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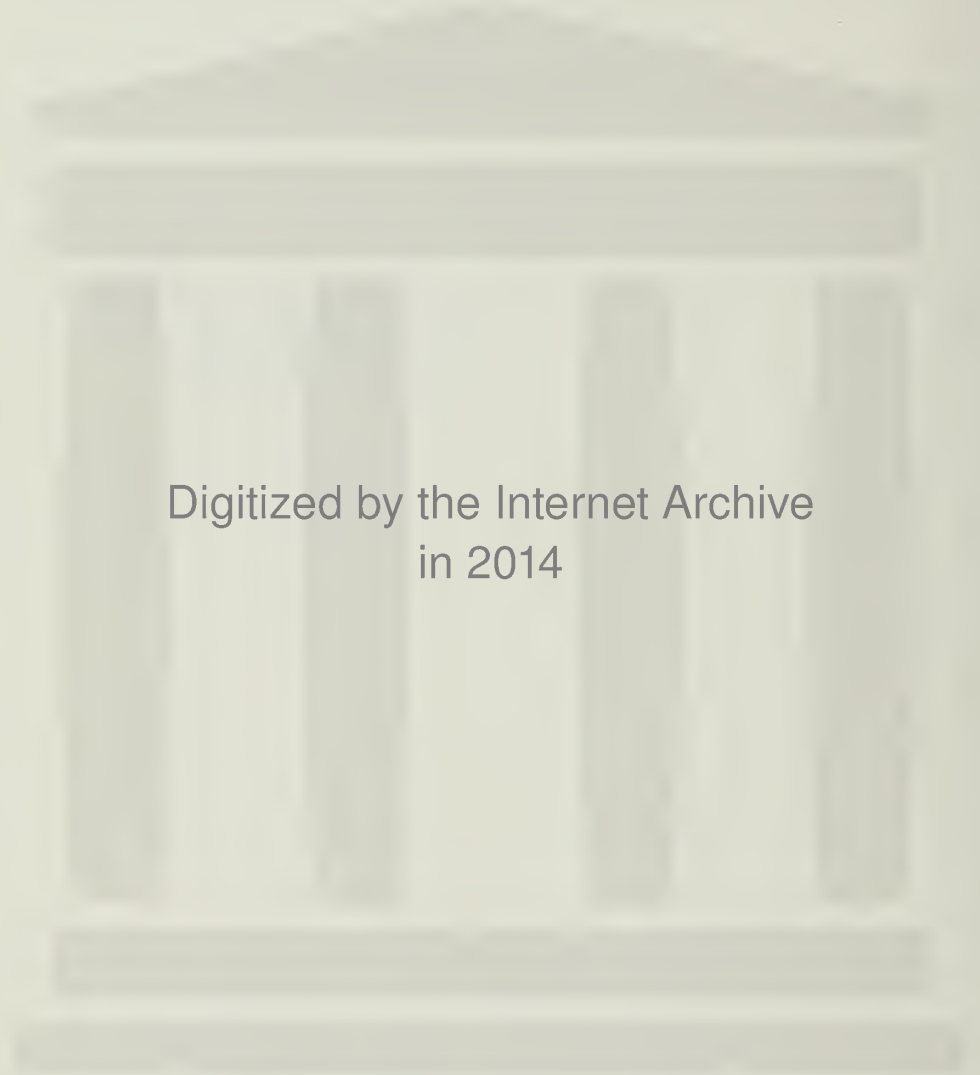

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San Francisco WASTEWATER TREATMENT PILOT PLANT STUDY

VOLUME I REPORT

DOCUMENTS

SAN FRANCISCO WASTEWATER TREATMENT PILOT PLANT STUDY

FOR
CITY AND COUNTY OF SAN FRANCISCO
DEPARTMENT OF PUBLIC WORKS

VOLUME I, REPORT

By

CH2M HILL, INC.
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May 1974

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ADDENDUM TO
SAN FRANCISCO WASTEWATER TREATMENT PILOT PLANT STUDY
September 1974

The pilot plant study was essentially completed by May 1974 and is being published in September 1974. The purpose of this Addendum is to update the study report in the light of developments between May and September 1974.

In August 1974, the San Francisco Bay Regional Water Quality Control Board issued tentative NPDES permits for the three San Francisco wastewater treatment plants. These tentative permits contain requirements which are at considerable variance with the requirements anticipated during the course of the pilot plant study. In effect the permits establish, with only minor variations, the same requirements for both ocean and bay discharge. The most significant factor is the requirement for 85 percent BOD removal for discharge to the ocean. Previously the requirements for ocean discharge of the State Water Resources Control Board made no reference to BOD removal.

The pilot plant study demonstrated conclusively that biological treatment will be necessary to assure meeting the 85 percent BOD removal requirement when treating any of the three San Francisco sewages.

The report outlines the many difficulties experienced in both primary and tertiary physical/chemical treatment of the sewages, including the problems of coagulant dosage control and density upsets, resulting from the wide variations in the characteristics of each of these sewages. In addition, studies completed

at Stanford University since May 1974 have further confirmed the difficulties to be encountered in the anaerobic digestion of chemically precipitated sludges.

It appears possible that sufficient land can be acquired at the Southeast site to permit expansion of the Southeast plant to provide biological treatment for both the Southeast and North Point sewages. However, at Richmond-Sunset, at least 10 acres of additional land would be required to accommodate a biological plant. To obtain this land would require either enroachment on Golden Gate Park or the condemnation of adjacent residential property. Either of these possibilities appears at this time to be politically impossible. Faced with these facts, the only alternatives remaining for the treatment of Richmond-Sunset sewage to meet the NPDES permit requirements are either the construction of a biological plant on a new site, perhaps in the vicinity of Lake Merced, or transport of the Richmond-Sunset sewage to the proposed new biological plant at the site of the Southeast plant.

Neither of these last two alternatives would provide improvement in the ocean conditions at Mile Rock until the Lake Merced ocean outfall and the transmission line from Richmond-Sunset to Lake Merced or the Southeast plant was completed. At that time the discharge at Mile Rock could be eliminated.

The Richmond-Sunset permit contains interim effluent settleable solids requirements to be met during the period while secondary facilities are being constructed. The present Richmond-Sunset plant cannot meet these requirements.

As a part of the pilot plant tests, plant scale tests were run at Richmond-Sunset in an attempt to develop a means of improving effluent quality by chemical coagulation. Various chemical

coagulants were used, however, because of the problems of chemical dosage control, high hydraulic loading of the sedimentation basins, and the facilities inadequate to handle the increased volume of sludge, the use of chemicals resulted in a deterioration rather than an improvement in effluent quality.

Improvement in the effluent quality at Richmond-Sunset by means of physical/chemical treatment would require extensive research in both the areas of solids handling and chemical coagulant dosage control. Even if such research were successful, there is no assurance that the facilities necessary to upgrade the existing plant could be constructed within the confines of the existing Richmond-Sunset site. It must, therefore, be concluded that physical/chemical treatment should not be considered as a possible solution to meeting even the interim requirements of the NPDES permit.

ABSTRACT

ABSTRACT
SAN FRANCISCO WASTEWATER TREATMENT
PILOT PLANT STUDY

The purpose of this project was to determine alternative treatment processes for the City and County of San Francisco to meet requirements for wastewater discharge to the Pacific Ocean or to San Francisco Bay. Processes for reuse or to meet future, more stringent requirements were also to be evaluated.

The $1.2 million project consisted of constructing a $175,000 pilot plant testing biological, biological-physical/chemical, and straight primary and tertiary physical/chemical treatment, each followed by filtration and activated carbon adsorption. Tests were run for each of the City's three treatment plants.

Major work elements included:

- Review of existing constituent data
- Influent characterization studies
- Pilot testing
- Analysis of results
- Economic evaluation of alternative processes

Process alternatives were determined to meet regulatory requirements at each plant, with the exception of the total chromium requirement. None of the processes tested could meet the chromium requirement.

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H-2	Pilot Centrifuge and Multiple Hearth Furnace Incineration Test Conducted for the Consulting Firm of CH2M HILL on Lime Sludge from the CH2M HILL Pilot Plant. Envirotech Systems, Inc., Laboratory Report, March 1974.
H-3	Laboratory Study on the Effects of Chemical Coagulants on Anaerobic Digestion of Richmond-Sunset Sludge. James M. Gossett and Perry L. McCarty, Consultant, Stanford, California, April 1974.
H-4	Phase II Report of Laboratory Study on the Effects of Chemical Coagulants on Anaerobic Digestion of Richmond-Sunset Sludge. Perry L. McCarty, Consultant, Stanford, California, August 1974.
I	Union Carbide High Purity Oxygen Report

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J	Southeast Test Data
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SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

NOTE TO THE READER

The complete report on the San Francisco Wastewater Treatment Pilot Plant Study is quite lengthy, consisting of several volumes. This summary section is intended as a brief but complete overview, highlighting results, conclusions, and a brief discussion of several special topics of particular interest and concern.

BACKGROUND

The City and County of San Francisco is served by a combined sewer system and three water pollution control plants. These three plants provide primary treatment with periodic low level ferric chloride additions for a tributary area of 25,000 acres (10,117 hectares) supporting a daytime population of 1,100,000 and a resident population of 730,000. Both the North Point Plant (65 mgd [2.85 cu m/sec])average dry weather ADW flow) and the Southeast Plant (20 mgd ADW [0.88 cu m/sec])discharge to San Francisco Bay. The Richmond-Sunset Plant (25 mgd ADW [1.1 cu m/sec])discharges to the Pacific Ocean. Solids are hauled to a sanitary landfill for disposal following digestion, elutriation, and vacuum filtration. Figure 1 shows the location and service area of each plant.

Many studies have been conducted to develop alternative methods of improving effluent quality from the existing treatment facilities as well as solving the City's storm water disposal problem. Expansion is difficult if not

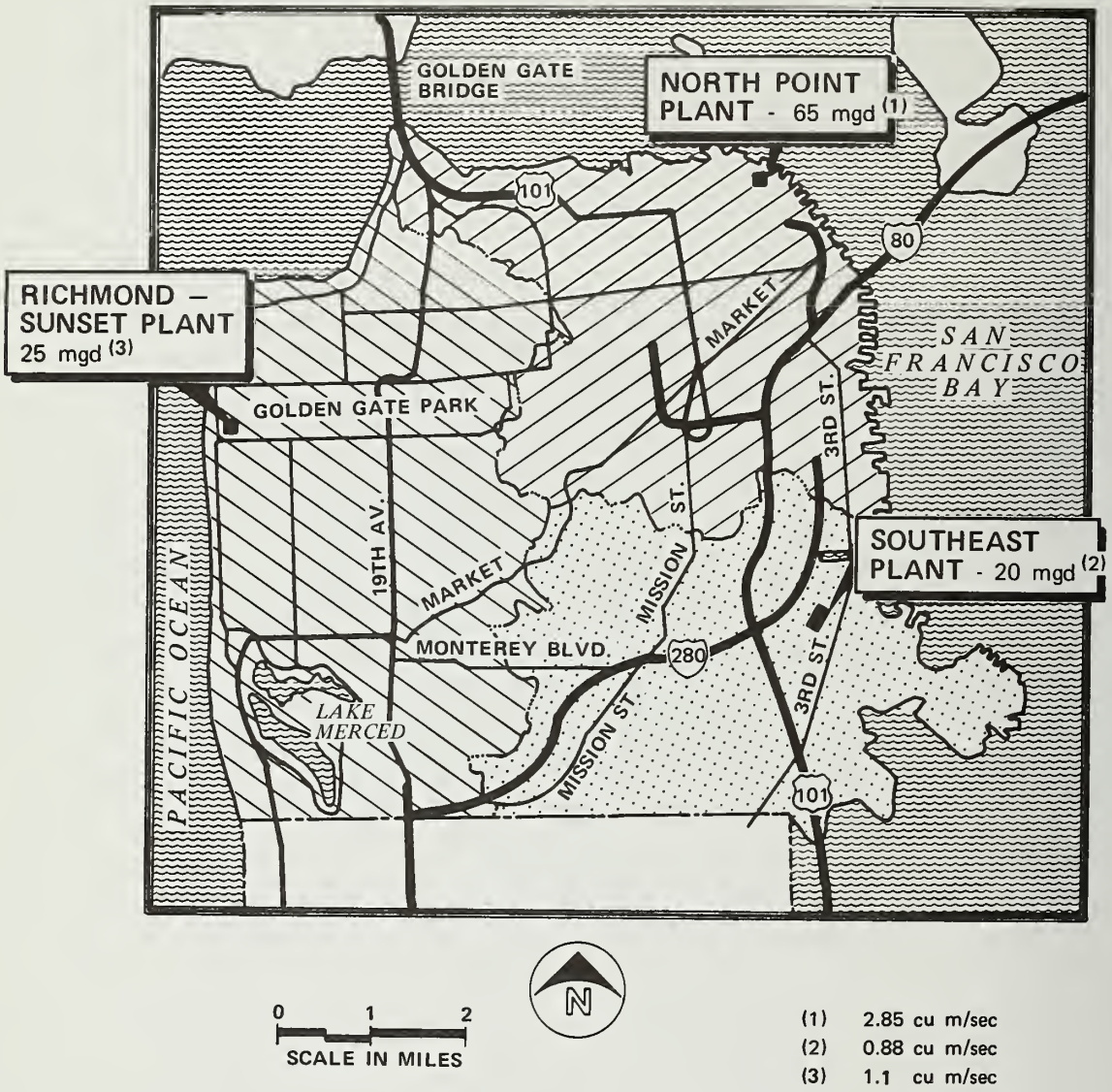


FIGURE 1

SAN FRANCISCO
WATER POLLUTION CONTROL PLANT
LOCATIONS AND SERVICE AREAS

impossible at North Point and Richmond-Sunset due to physical and environmental restrictions at those sites.

The Richmond-Sunset Plant is located in the westerly end of Golden Gate Park, and the North Point Plant is in the highly developed northern waterfront. Increasingly stringent discharge standards require continuous plant upgrading. A principal objective of this project was a study alternative processes to meet present and future discharge requirements.

In July, 1972, the City was faced with the following discharge requirements:

- The State of California Water Resources Control Board (SWRCB) Ocean Policy
- Environmental Protection Agency (EPA) requirements for secondary treatment.
- The San Francisco Bay Regional Water Quality Control Board (RWQCB) tentative Bay discharge requirements.

Table 1 summarizes these requirements.

The objective of this project was to quantify all influent constituent masses and determine removal efficiencies for various pilot processes. Candidate processes were selected which potentially could meet existing and anticipated discharge requirements for both the Bay and the Ocean. The feasibility of producing an effluent usable for irrigation, industrial reuse, or ground water recharge was also to be

TABLE 1
DISCHARGE REQUIREMENTS

CONSTITUENT		DISCHARGE REQUIREMENTS					
		OCEAN[1]		EPA[2]		BAY[3]	
		50%	10%	30-day	7-day	50%	10%
PHYSICAL							
Floatables	mg/l	1.0	2.0	NONE		NONE	
Grease and Oil	mg/l	10	15	NONE		5	
Suspended Matter	mg/l	50	75	30	45	15	
				85%[4]			
Settleable Matter	ml/l/hr	.1	.2	NONE		.1	
Turbidity	JTU	50	75	NONE		10	
CHEMICAL:							
BOD_5	mg/l	NONE		30	45	—	—
	%			85%		85%	
Arsenic	mg/l	.01	.02	NONE		.01	.02
Cadmium	mg/l	.02	.03	NONE		.02	.03
Total Chromium	mg/l	.005	.01	NONE		.005	.01
Copper	mg/l	.2	.3	NONE		.2	.3
Lead	mg/l	.1	.2	NONE		.1	.2
Mercury	mg/l	.001	.002	NONE		.001	.002
Nickel	mg/l	.1	.2	NONE		.1	.2
Silver	mg/l	.02	.04	NONE		.02	.04
Zinc	mg/l	.3	.5	NONE		.3	.5
Cyanide	mg/l	.1	.2	NONE		.1	.2
Phenolic	mg/l	.5	1.0	NONE		.5	1.0
Total Cl_2 Residual	mg/l	1.0	2.0	NONE		1.0	2.0
Ammonia (N)	mg/l	40	60	NONE		40	60
TICH	mg/l	.002	.004	NONE		.002	.004
pH	—	6.0-9.0		6.0-9.0		6.5-8.5	
TOXICITY:	Various	1.5 tu	2.0 tu	NONE		40 ml/l (RT)	

1. California State Water Resources Control Board — "Water Quality Control Plan — Ocean Waters of California" July 6, 1972.
2. Environmental Protection Agency — Federal Register Vol. 3S, No. 159, Part II, "Water Programs — Secondary Treatment Information".
3. California Regional Water Quality Control Board — San Francisco Bay Regions Basin Plan — Tentative Water Quality Objectives and Waste Discharge Prohibitions—Dec. 19, 1972.
4. The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 15 percent of the arithmetic mean of the values for influent samples collected at approximately the same times during the same period (85 percent removal).

assessed. A "building block" approach was envisioned which would provide the basis for evaluating the cost effectiveness of incremental construction to meet more stringent requirements or respond to changes in the economics of water reuse.

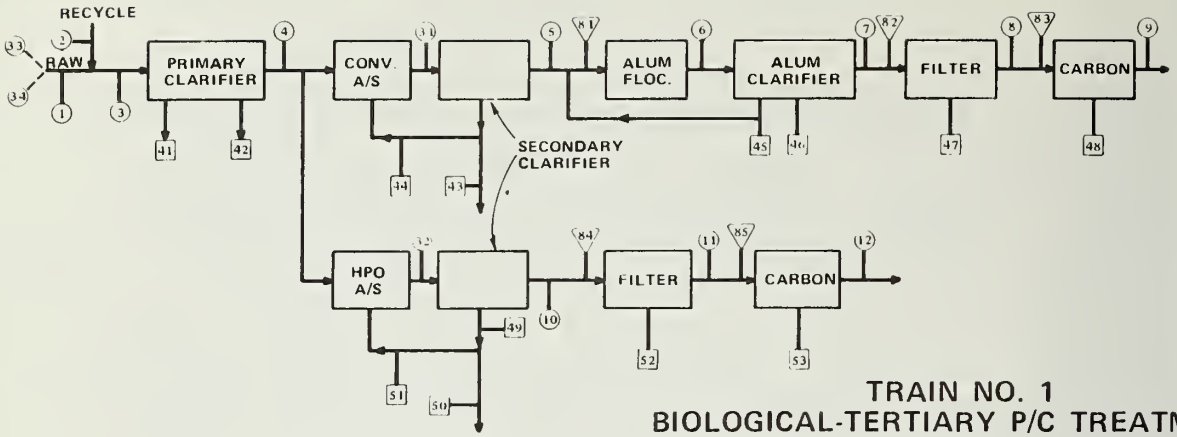
The process trains and sample points finally adopted are depicted in Figures 2, 3, and 4.

PROJECT ELEMENTS

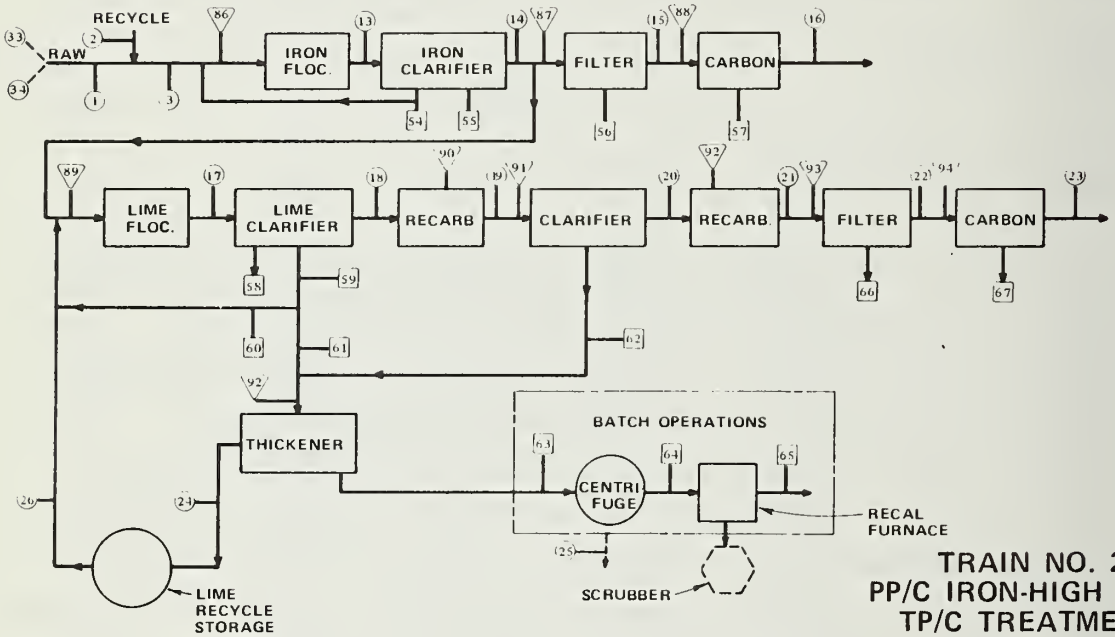
Existing Data Review

To assure that the study did not duplicate work by others, an extensive investigation was made of available data throughout the country. It was originally hoped that the data from various research projects and actual plant operations could be assembled by process and constituent removal, and then statistically analyzed. After collecting several thousand data bits, no practical method was found for combining data from one source with that from another because of the paucity of data related to any particular sequence of processes. Seldom were the processes the same or even similar. Data were categorized as follows:

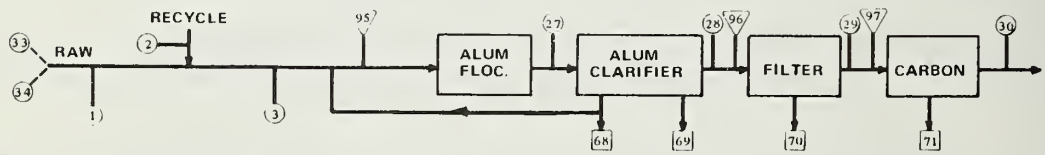
- Conventional Activated Sludge
- Pure Oxygen Activated Sludge
- Biological Treatment plus Direct Filtration
- Biological Treatment plus Chemical/Physical Treatment
- Low Ferric Chloride Tertiary Physical/Chemical



TRAIN NO. 1
BIOLOGICAL-TERTIARY P/C TREATMENT



TRAIN NO. 2
PP/C IRON-HIGH LIME
TP/C TREATMENT



TRAIN NO. 3
TERTIARY PHYSICAL/CHEMICAL TREATMENT

NOTES:

① TO ㉞	LIQUID STREAM DATA POINTS
[41] TO [71]	SOLID OR WASTE DATA POINTS
▽81 TO ▽97	CHEMICAL ADDITION POINTS
– – – –	INDICATES NP + SE
㉝	SE RAW
㉞	NP RAW

FIGURE 2

SOUTHEAST PILOT PLANT
PROCESS TRAINS AND DATA COLLECTION POINTS

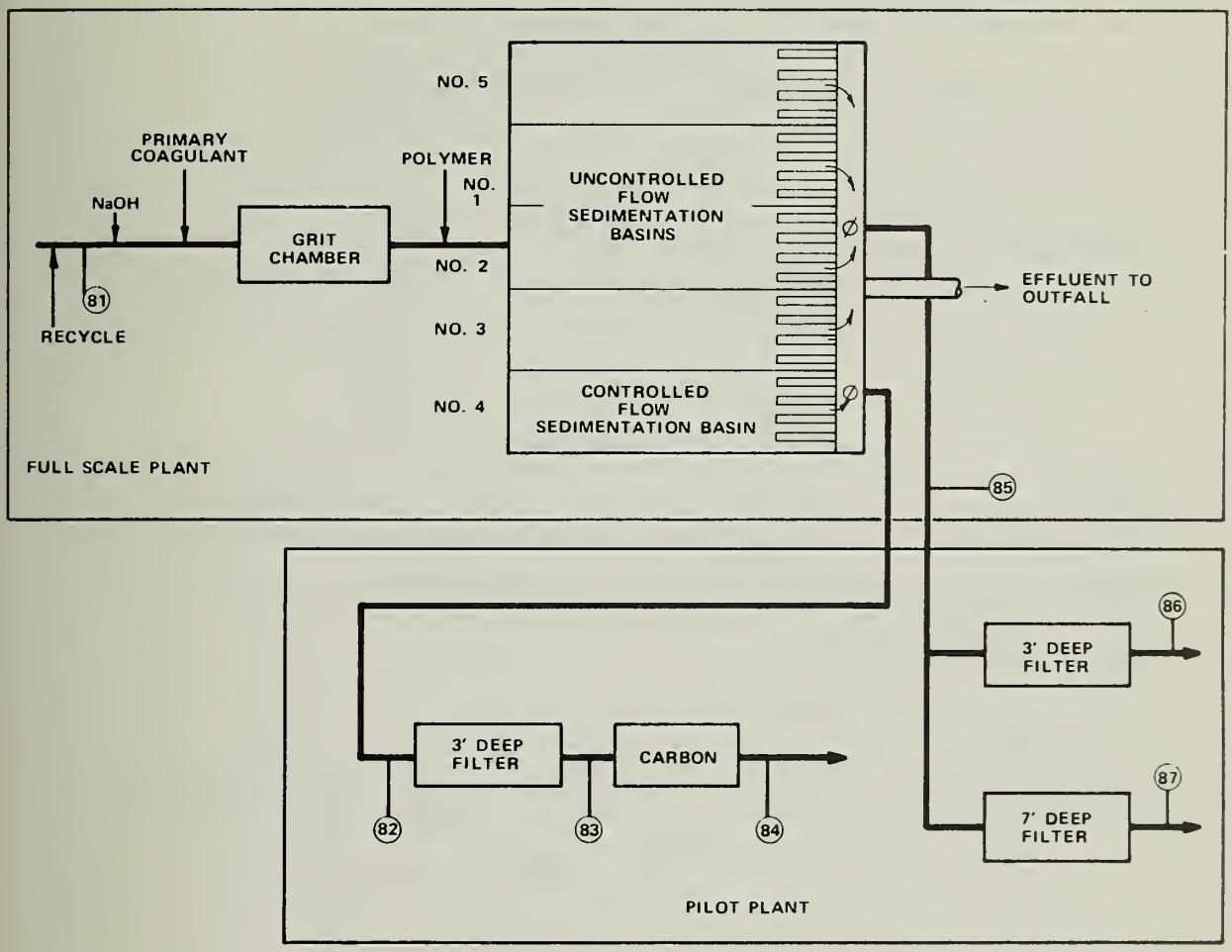


FIGURE 3

RICHMOND – SUNSET
PROCESS TRAINS AND DATA COLLECTION POINTS
FERRIC CHLORIDE AND ALUM TESTS

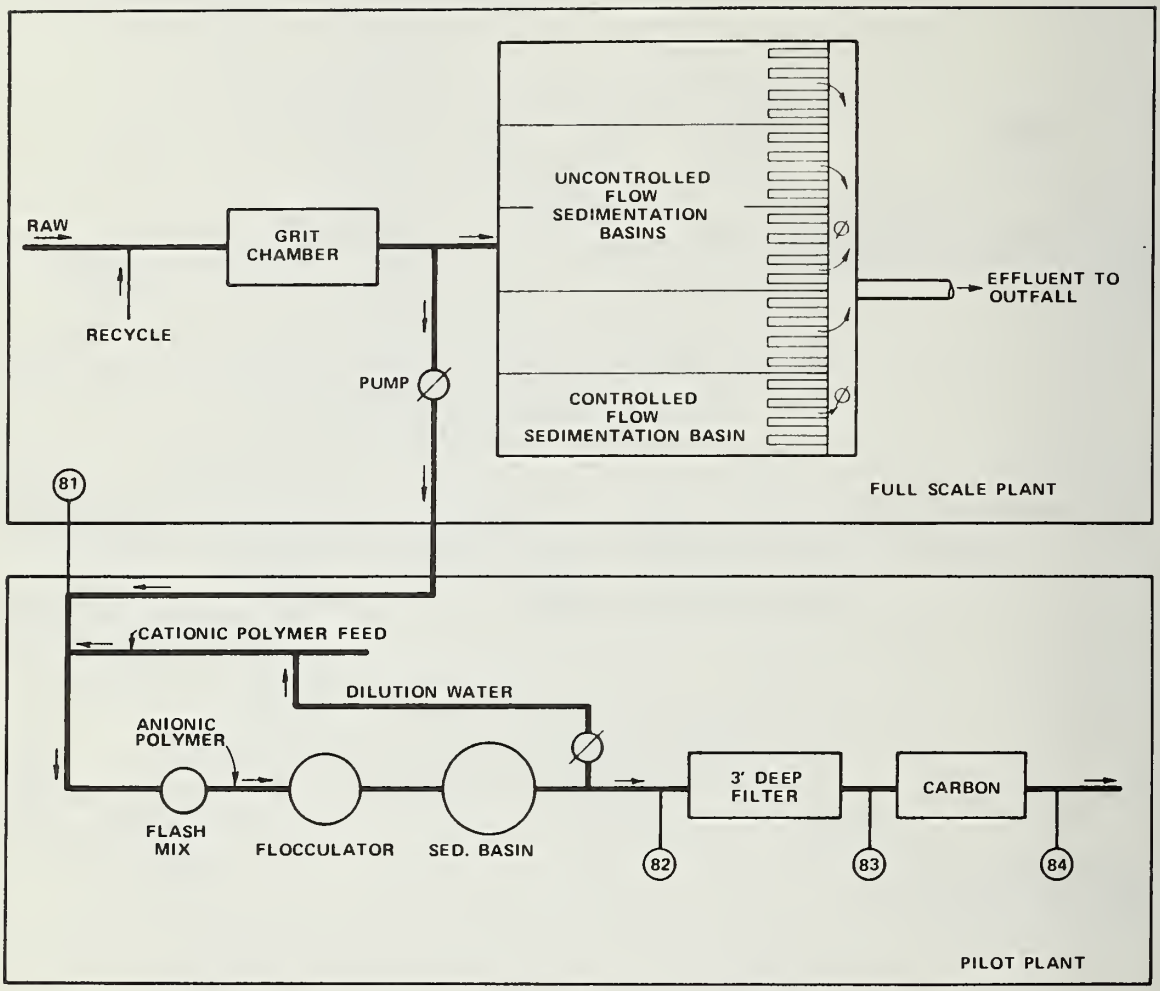


FIGURE 4

RICHMOND – SUNSET
PROCESS TRAINS AND DATA COLLECTION POINTS
CATIONIC POLYMER TEST

- Lime Tertiary Physical/Chemical
- Nitrogen Removal
- High Alum or Ferric Chloride Tertiary Physical/Chemical

The data from each source and for each constituent were plotted separately, resulting in over 400 statistical plots. Several attempts were made to accurately summarize these data. However, the many variations made this impractical. As a result, the data were simply cataloged and placed on file with the San Francisco Department of Public Works.

A review of these data plus an extensive influent characterization program did indicate that so long as the constituents of concern in the San Francisco sewages remained approximately at the measured levels any of the treatment processes under consideration could produce effluent meeting most of the anticipated requirements. An exception was the chromium requirement. It appeared at the outset that none of the processes could meet the proposed requirement of 0.005 mg/l of chromium. This proved to be the case. The review also pointed out the potential inability of physical/chemical process trains to meet the BOD removal requirements.

Influent Characterization Program

In conjunction with the data review, a sampling and analysis program was conducted at each plant to fully characterize the influent sewage. This program provided data to estimate the levels of constituents expected at each plant during the pilot plant operation and to provide a basis for the pilot plant operational sampling schedule. The

sampling program involved the collection of 24-hour, flow proportioned composite samples, and a peak flow grab sample on alternate days over a 2-week period. The sampling program at each plant was conducted concurrently from April 16-28, 1973. In all, 42 samples were obtained, each of which was analyzed for 108 constituents. Analyses were performed by four state certified laboratories using techniques described in Standard Methods for the Examination of Water and Wastewater (Edition 13) or by other approved methods.

Data received during the influent characterization program were filed in accordance with EPA's Storet system in a central computer. Apparent anomalies in the data were identified, investigated, and corrected when errors were found.

During the sampling study influent pH values varied greatly. The following table depicts the range of pH values at each sewage treatment plant:

TABLE 2
RAW SEWAGE pH VALUES

Plant	Maximum pH	Minimum pH	Range
Southeast	10.4	3.1	7.3
North Point	9.6	5.7	3.9
Richmond-Sunset	8.5	6.1	2.4

The large range and erratic pH fluctuations at the Southeast plant suggested significant intermittent industrial discharges. pH values often varied over 3 pH units between

half-hour analyses. pH variations of this magnitude over such a short time period, in approximatley 20 mgd (0.88 cu m/sec) flow, can only be accounted for by major industrial releases.

Data on heavy metals in the Southeast sewage also verified the significance of industrial discharges in the Southeast service area. Concentrations of many metals associated with industrial discharges at Southeast are 5 to 10 times the concentrations at North Point and Richmond-Sunset.

The other major finding of the influent characterization program was the high and variable quantity of seawater in both the Southeast and North Point sewages.

Due to the predominance of industrial discharges at Southeast, an industrial waste and salinity survey was conducted. The survey consisted of continuous survelliance by the pilot plant operators of the raw sewage characteristics and an intensive one week sampling program. Included were one-half hour analyses for pH and chloride on samples from thirteen different manholes on sewers tributary to the Southeast plant. The data identified the portions of the sewer system which were responsible for the wide fluctuations of pH and salinity at the Southeast plant.

Pilot Plant

Following selection of processes to be tested (see Figures 2 and 3), the pilot plant was designed, constructed and placed in operation at the Southeast plant in July, 1973.

The original concept was to collect statistical samples for 25 days at Southeast, then move the pilot plant to

North Point for testing there. However, the scope of the project and the size and complexity of the pilot plant grew to such proportions that it became more practical, and more economical, to move the North Point sewage to the pilot plant than to move the pilot plant to North Point.

The decision to haul North Point sewage to Southeast for testing also made it possible to simulate conditions which will result for implementation of the City's Master Plan. As planned, North Point will be phased out as a dry weather treatment facility. North Point sewage will be pumped to Southeast for treatment and disposal through an expanded plant. Thus, by hauling 5,000 gal/hour (18,940 l/hr) each hour, 24 hours per day, and mixing three parts of North Point sewage to one part of Southeast sewage, the pilot plant treated a sewage approximating the actual sewage which will result from the consolidation of the two plants.

Following tests on Southeast and the combined North Point-Southeast sewage, tests began at Richmond-Sunset. Only physical/chemical processes were tested at Richmond-Sunset. The ample data was available on biological processes, plus site restrictions at Richmond-Sunset, strongly favored the more compact physical/chemical processes, providing discharge requirements could be met.

Data

Section VIII presents details on data collection, processing, and presentation. The raw data are presented in a series of appendices, but summaries are presented throughout the report.

There are two basic bodies of data--that analyzed by state-certified laboratories, and the operating data analyzed in a mobile laboratory at the pilot plant site.

Results

Summaries of results are included in this summary for each process train. In addition, process requirements to meet each discharge requirement are shown. Section IX amplifies these summaries and Appendices J, K, and L present the complete body of data.

Economic Evaluation

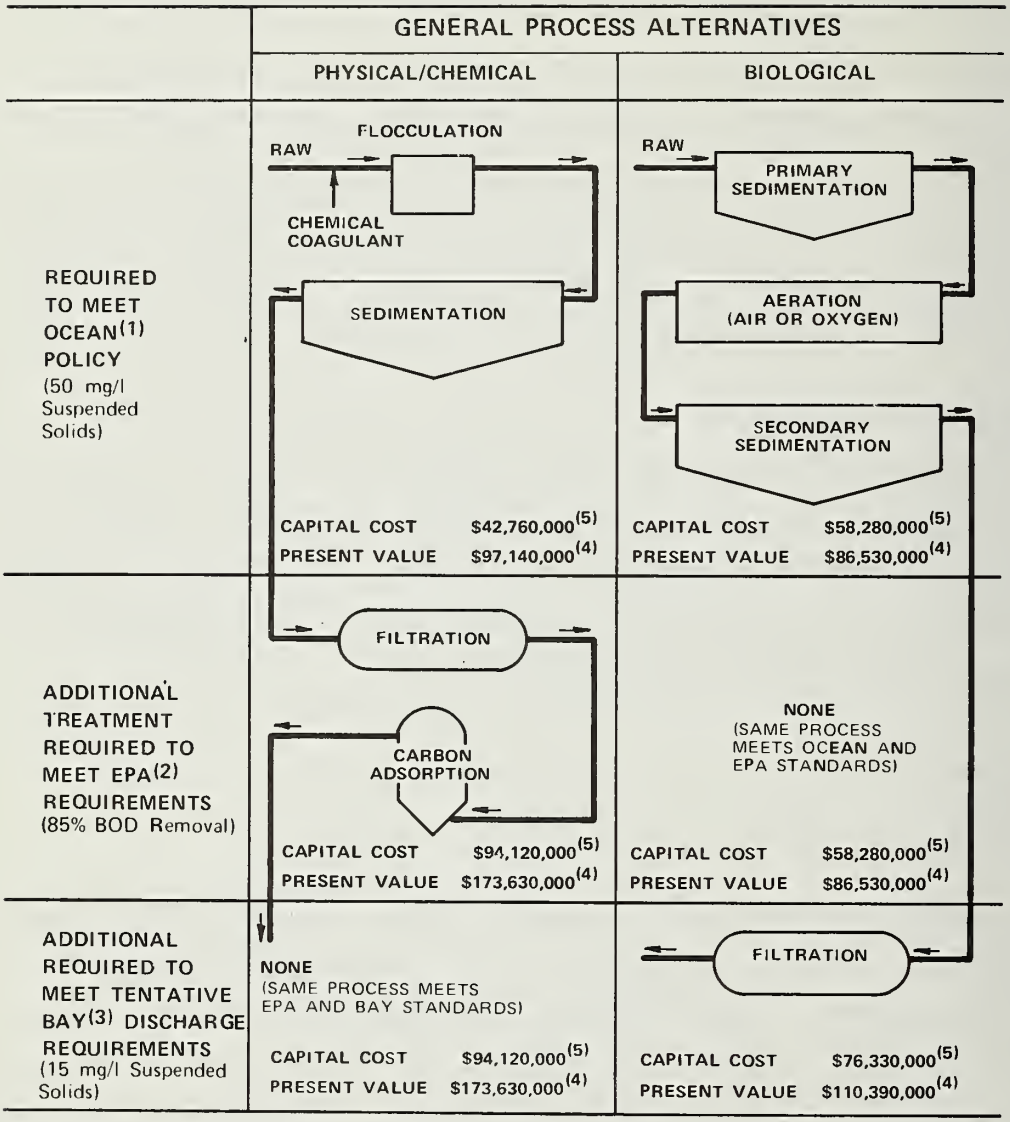
The objective of the economic evaluation was to show comparative costs and area requirements for each incremental process "building block." These data were used to compare the costs of alternative process trains, each capable of meeting discharge requirements.

Section X discusses the economic evaluation in detail. Summary cost data is included in Figure

Cost data are based on January, 1974, total present value cost (capital plus operation and maintenance) assuming a 5.625% discount rate, phased construction, and a 20-year amortization period. The estimates are "order of magnitude" values only, and are intended to be used only for comparative purposes. Estimates do not include the cost of land or pile foundations.

SPECIAL TOPICS

Through the pilot plant study, four significant areas of concern were identified which merit additional discussion:



1. CALIFORNIA STATE WATER RESOURCES CONTROL BOARD - "WATER QUALITY CONTROL PLAN - OCEAN WATERS OF CALIFORNIA" JULY 6, 1972.
2. ENVIRONMENTAL PROTECTION AGENCY - FEDERAL REGISTER VOL. 38, NO. 159 PART II, "WATER PROGRAMS - SECONDARY TREATMENT INFORMATION".
3. CALIFORNIA REGIONAL WATER QUALITY CONTROI BOARD - SAN FRANCISCO BAY REGION, BASIN PLAN - TENTATIVE WATER QUALITY OBJECTIVES AND WASTE DISCHARGE PROHIBITIONS - DECEMBER 19, 1972.
4. APPROXIMATE TOTAL PRESENT VALUE COST INCLUDING O&M.
5. DOES NOT INCLUDE LAND OR PILE FOUNDATION COSTS.

FIGURE 5

NORTH POINT – SOUTHEAST
PROCESS ALTERNATIVES AND COMPARATIVE COSTS
100 MGD (4.38 m^3/s) NOMINAL CAPACITY

- o Salt water in the Southeast and North Point sewages
- o Industrial waste
- o Alkalinity
- o Anaerobic digestion of chemically precipitated sludges

Saltwater

In the City's combined sewer system, there are many overflow structures along the waterfront where combined sewage in excess of the treatment plant capacities is periodically released. Leakage problems are common with the tide gates on these outlets. In addition many sewers are built below the water level of San Francisco Bay. These sewers are old and leak in some areas. This saltwater intrusion from leakage and infiltration results in major changes in the sewage characteristics. There is some evidence of periodic industrial discharges of saltwater (possibly used for cooling) as well. Conductivity at Southeast ranged from 2000 to 13,500 micromhos. At any time during which there was a significant drop in salinity (decrease in density) of the sewage, the physical/chemical clarifiers in the pilot plant would become upset and lose sufficient flocculated solids to make filtration of the effluents impractical. It became necessary during the pilot plant testing to shut down the filters during periods of upset. If not shut down, filter runs would be reduced to less than an hour by excessive head loss buildup during these upset periods. As the incoming sewage density (salinity) decreases, the lighter incoming sewage overrides the heavier sewage already in the sedimentation basin and short-circuits directly to the effluent weir. The problem was dramatically noticeable in the pilot plant basins where large quantities of well-coagulated solids were periodically observed going over

the effluent weir. While the volume of these solids was sufficiently high as to preclude filtration, the weight of suspended solids lost on a daily basis was relatively low. Thus the effluent continued to meet the suspended solids requirements of the SWRCB Ocean Discharge Policy. However, any process that requires filtration downstream from a chemical clarifier requires that attention be given to the solution of the density problem before the process can be considered practical.

High salinity levels also interferred with the COD analysis. At the levels of chlorides encountered, COD analyses lower than 250 mg/l were unreliable.

Variations in seawater content of the sewage also resulted in major changes in the magnesium content of the raw sewage. The impact of magnesium levels on coagulation with lime was threefold:

- With high magnesium levels coagulation and clarification were excellent, but sludge thickening and dewatering to reasonable levels were not possible.

- With low magnesium levels (in the absence of seawater), clarification suffered.

- With high magnesium levels, recalcination of lime-coagulated sludges was not practical.

Saltwater variations plus changing sewage characteristics in wet weather also complicated coagulant control. Presently available equipment cannot change dosage rapidly enough to keep pace with these rapidly changing sewage

characteristics. High saltwater levels broadened the effective range of all coagulants tested. At low saltwater levels, much closer coagulant control was required.

With the total dissolved solids and chloride levels encountered, deionization would be required prior to reuse of North Point-Southeast effluent. Thus, a major impact of saltwater intrusion is to make reuse impractical. This is particularly significant in view of the current emphasis and interest in reuse possibilities.

Industrial Waste

Effective control of industrial waste discharges will be necessary for the successful operation of the processes considered. Specific problems related to industry which were noted during pilot tests included:

- Rapidly changing pH, often varying 3 pH units in a half hour.
- Intermittent discharge of high carbonaceous BOD
- Discharge of debris which complicated plant operation.
- Intermittent discharges of large volumes of saltwater.

The impacts of industrial discharges were far less noticeable on the combined North Point-Southeast tests than on Southeast alone due to the diluting effect of the relatively uniform North Point sewage. Nevertheless, industrial control will be a prerequisite to successful operation of any new treatment facility at Southeast.

Alkalinity

San Francisco's source of water supply is the Tuolumne River basin, on the western slope of the Sierra Nevada Mountains. The raw water is of exceptionally high quality with very low mineral content and alkalinity. During wet weather, discharge of rain water into the combined sewage system also reduces the sewage alkalinity.

Changing alkalinity levels complicate coagulant control in the physical/chemical processes. Dosage requirements vary widely in dry weather and wet weather, due in part to changing alkalinity.

Digestion

When full-scale tests of alum coagulation began at Richmond-Sunset, a rapid loss of gas production to 60% of former levels occurred in the anaerobic digesters. Apparently at the chemical doses necessary for coagulation at Richmond-Sunset, digestion problems result. A data search revealed no information from other plants on anaerobic digestion of chemically-treated sludges using the high levels of coagulant required at Richmond-Sunset.

An experimental program was designed and is ongoing in cooperation with Stanford University. Study results will show effects on digestion of varying levels of alum, ferric chloride, and a cationic polymer (American Cynamid's Magnifloc 509-C).

Results

Results of the pilot plant tests are summarized in the tables and figures which follow.

Tables 3 and 4 show 50% values for the Southeast tests and the North Point-Southeast tests for the following processes:

1. Raw sewage (untreated)

2. Conventional (Air) Activated Sludge

   - o With secondary clarification and no further treatment.

   - o With secondary clarification followed by alum coagulation, clarification, filtration, and carbon adsorption.

3. High Purity Oxygen Activated Sludge

   - o With secondary clarification and no further treatment.

   - o With secondary clarification plus filtration

   - o With secondary clarification followed by filtration and carbon adsorption.

4. Ferric Chloride Coagulation

   - o With clarification and no further treatment

   - o With clarification followed by filtration and carbon adsorption.

   - o With clarification followed by lime coagulation and clarification plus two-stage recarbonation.

TABLE 3

SOUTHEAST TEST PROGRAM
CONSTITUENTS IN DISCHARGE REQUIREMENTS
PROCESS 50% VALUES

	UNITS	STAN-DARD (1)	PROCESS	CONV. A/S		H.P.O. A/S			FERRIC CHLORIDE COAGULATION				ALUM COAG.	
			RAW SEWAGE	SED. ONLY	PLUS ALUM FILT. CARB.	SED. ONLY	PLUS FILT.	PLUS FILT.& CARB.	SED. ONLY	PLUS FILT.& CARB.	PLUS LIME & RECARB	PLUS LIME FILT.& CARB.	SED. ONLY	PLUS FILT.& CARB.
SAMPLE POINT			1	5	9	10	11	12	14	16	21	23	28	30
METALS														
Arsenic	µg/l	10(2)	3.5	1.9	1	2		1	1	1	1	1	1	1
Cadmium	µg/l	20(2)	5.7	1	1	1		1	1	1	1	1	1	1
Chromium (T)	µg/l	5(2)	1,600	95	18	210		45	93	25	25	21	98	26
Copper	µg/l	200(2)	194	11	5	18		5	15	7.5	5	5	15	8
Cyanide	mg/l	0.1(2)	0.04	0.01	0.01	0.01		0.01	0.01	0.01	0.02	0.01	0.02	0.01
Lead	µg/l	100(2)	190	17	5	19		5	8	5	5	5	10	5
Mercury	µg/l	1(2)	1.3	1	1	1		1	1	1	1	1	1	1
Nickel	µg/l	100(2)	95	46	33	53		53	62	45	19	12	45	15
Silver	µg/l	20(2)	28	1.5	1	3		1.3	2.2	1.4	1	1	2.5	1.1
Zinc	µg/l	300(2)	700	150	102	220		140	170	110	19	28	140	20
CHEMICAL														
BOD_5	mg/l	30(3)	267	11.6	3.2	10		3.2	73	29.1	44	26.3	62	23.7
BOD_5(4)	% Remove	85(3)		94	98	95		98	70	88	82	86	76	89
Oil & Grease	mg/l	5(5)	84	2.6	2	2.6		1.8	2.6	2.2	1.8	1.7	4.6	2.4
Phenol	µg/l	500(2)	300	24	1	30		1	310	1	300	1	300	1
NUTRIENTS														
Ammonia	mg/l	40(2)	14.8	8.2(6)	6.2(6)	14		14.8		14		13		13.8
PHYSICAL														
Floatables	mg/l	1(2)	6.5	2.7	0.3	2.7		0.3	1.3	0.3	1.9	0.3	1.7	0.5
Settleable Solids	ml/l	0.1(2)	9	0.1	0.1	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1
Suspended Solids	mg/l	15(5)	324	26	2.4	31	12	5.3	30	6.3	9	4.3	36.8	8.6
Turbidity (4)	FTU	10(5)	118	10	1.2	20	3	4	20	2.7	9.8	2	22	9.4
BIOASSAYS														
Toxicity	tu	1.5(2)	0.09	0	0	0		0	0	0	0	0	0	0.8
TCHC	µg/l	2(2)	1.3	0.30	0.08	0.47		0.072	0.16	0.028	0.14	0.037	0.15	0.019

(1) Most stringent standard for other standards see table 9-3.
(2) SWRCB
(3) EPA
(4) Average Values
(5) RWQCB
(6) Conv. A/S was nitrifying

TABLE 4

NORTH POINT – SOUTHEAST TEST PROGRAM
CONSTITUENTS IN DISCHARGE REQUIREMENTS
PROCESS 50% VALUES

	UNITS	STANDARD (1)	PROCESS	CONV. A/S		H.P.O. A/S			FERRIC CHLORIDE COAGULATION				ALUM COAG.	
			RAW SEWAGE	SED. ONLY	PLUS ALUM FILT. CARB.	SED. ONLY	PLUS FILT.	PLUS FILT.& CARB.	SED. ONLY	PLUS FILT.& CARB.	PLUS LIME & RECARB	PLUS LIME FILT.& CARB.	SED. ONLY	PLUS FILT.& CARB.
SAMPLE POINT			1	5	9	10	11	12	14	16	21	23	28	30
METALS														
Arsenic	µg/l	10(2)	2.4	2	1	1.6		2	1	1	1	1	1	1
Cadmium	µg/l	20(2)	3.1	1.2	1	1.3		1	1	1	1	1	1	1
Chromium (T)	µg/l	5(2)	435	94	33	140		40	54	40	40	32	71	40
Copper	µg/l	200(2)	150	14	89	20		5	8	40	5	8	15	10
Cyanide	mg/l	0.1(2)	0.03	0.01	0.01	0.01		0.01	0.02	0.01	0.01	0.01	0.02	0.01
Lead	µg/l	100(2)	110	18	5	22		5	7	5	5	5	10	5
Mercury	µg/l	1(2)	1.2	1	1	1		1	1	1	1	1	1	1
Nickel	µg/l	100(2)	48	32	20	40		30	41	30	19	16	27	20
Silver	µg/l	20(2)	31	3	2	3.2		1	1	2	1	1	2.4	1
Zinc	µg/l	300(2)	580	290	63	320		230	200	34	22	28	100	37
CHEMICAL														
BOD_5	mg/l	30(3)	210	7(7)	2.5(7)	6.9		3.4	33.9	14.4(7)	32	21.5	33	5.6(7)
BOD_5(4)	% Remove	85(3)		93	99	96		98	83	90	83	87	81	94
Oil & Grease	mg/l	5(5)	29.4	2	1.6	2.4		1.6	1.6	1.2	2.6	1.0	2.0	1.0
Phenol	µg/l	500(2)	170	9	2	11		1	50	1	100	1	50	1
NUTRIENTS														
Ammonia	mg/l	40(2)	14.4	0.57(6)	0.48(6)	12.4		12		13.6		12.8		13.6
PHYSICAL														
Floatables	mg/l	1(2)	0.5	0.2	0.1	0.3		0.1	0.1	0.1	0.2	0.1	0.1	0.1
Settleable Solids	ml/l	0.1(2)	3.2	0.1	0.1	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1
Suspended Solids	mg/l	15(5)	174	16	1.9	24	10	2.3	19.5	5	6.3	3.9	31	4.3
Turbidity(4)	FTU	10(5)	95	6.7	0.4	9.9	2.5	0.7	4.8	1.9	5.1	0.7	11	2.7
BIOASSAYS														
Toxicity	tu	1.5(2)	0	0	0	0		0	0	0	0	0	0	0
TCHC	µg/l	2(2)	0.5	0.06	0.016	0.04		0.018	0.04	0.011	0.05	0.012	0.07	0.007

(1) Most stringent standard for other standards see table 9-3.

(2) SWRCB

(3) EPA

(4) Average Values

(5) RWQCB

(6) Conv. A/S was nitrifying

(7) Carbon column was acting as anaerobic biological filter.

- o With clarification followed by lime coagulation and clarification, two-stage recarbonation, filtration, and carbon adsorption.

5. Alum Coagulation

   - o With clarification and no further treatment.
   - o With clarification followed by filtration and carbon adsorption.

Sample points shown on the tables refer to numbered points on the process schematics, Figure 2 and Figure 3.

Table 5 shows similar constituent data on the alum coagulation test at Richmond-Sunset. It should be noted that the sewage during this test was relatively weak. Subsequent test results on stronger sewage produced results similar to those obtained during the North Point-Southeast test.

The extensive test programs on the Southeast and North Point-Southeast sewages established process capabilities to such an extent that the same level of effort was not required at Richmond-Sunset. Thus, neither biological tests nor the lengthy test periods were used at Richmond-Sunset.

Values in Table 5, the Richmond-Sunset data, represent average values based on 3 to 11 samples, depending on the constituent. Conversely, Tables 3 and 4 show 50% values from 25 composite samples.

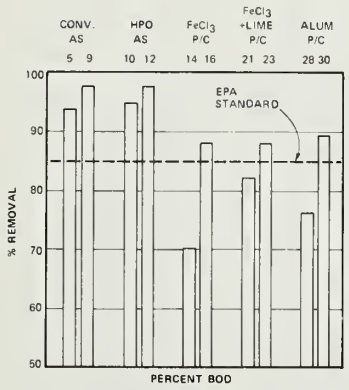
The most difficult sewage to treat is the Southeast sewage alone. Figure 6 summarizes removals graphically at Southeast for the following:

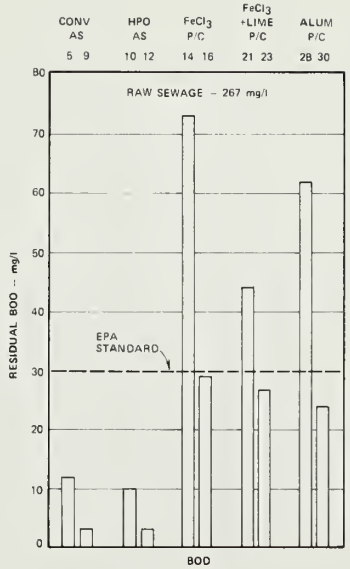
TABLE 5

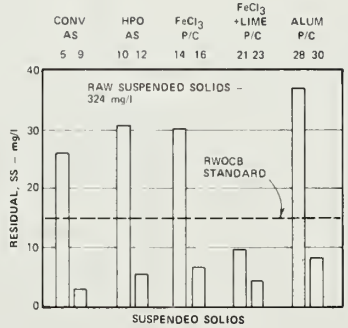
RICHMOND-SUNSET PROGRAM
CONSTITUENTS IN DISCHARGE REQUIREMENTS
AVERAGE VALUES

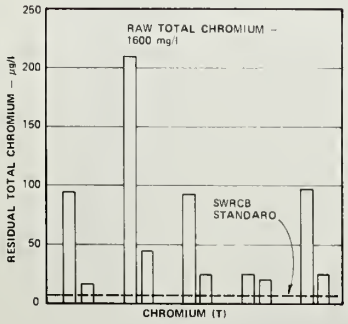
	UNITS	STAN-DARD (1)	PROCESS	ALUM COAGULATION			
			RAW SEWAGE	SEDIMENTATION ONLY	PLUS FILTRATION	PLUS CARBON	NO. OF DATA POINTS
SAMPLE POINT			81	82	83	84	
METALS							
Arsenic	µg/l	10 (2)	3.0	1.6	1.4	1.0	5
Cadmium	µg/l	20 (2)	1.8	1.0	1.0	1.0	5
Chromium (T)	µg/l	5 (2)	29	14	12	10	5
Copper	µg/l	200 (2)	70	16	30	6	5
Cyanide	mg/l	0.1 (2)	10				3
Lead	µg/l	100 (2)	100	25	14	7.5	5
Mercury	µg/l	1 (2)	1.1	1	1	1	5
Nickel	µg/l	100 (2)	14	16	14	18	3
Silver	µg/l	20 (2)	12	4	3.4	1.3	5
Zinc	µg/l	300 (2)	200	100	130	130	3
CHEMICAL							
BOD_5	mg/l	30 (3)	141	34	23.5	9.4	11
BOD_5 (4)	% Remove	85 (3)					
Oil & Grease	mg/l	5 (5)	47.2	4.4	1.0	1.8	11
Phenol	µg/l	500 (2)	130	50	50	4	5
NUTRIENTS							
Ammonia	mg/l	40 (2)	18	13.2	12.4	11.4	11
PHYSICAL							
Floatables	mg/l	1 (2)	5.4	0.2	0.1	0.1	11
Settleable Solids	ml/l	0.1 (2)	6.0	0.3	0.1	0.1	11
Suspended Solids	mg/l	15 (5)	159	35	7.8	2.0	11
Turbidity (4)	FTU	10 (5)	70	17.2	1.9	2.8	11
BIOASSAYS							
Toxicity	tu	1.5 (2)	0.0	0.0	0.0	0.0	5
TCHC	µg/l	2 (2)	0.3	0.04	0.02	0.008	3

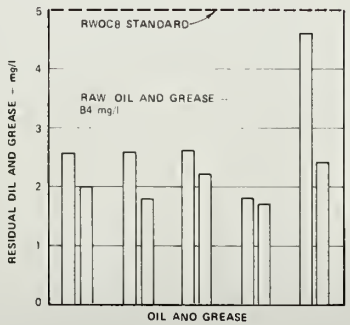
(1) Most stringent standard for other standards see table 9-3.
(2) SWRCB
(3) EPA
(4) Average Values
(5) RWQCB

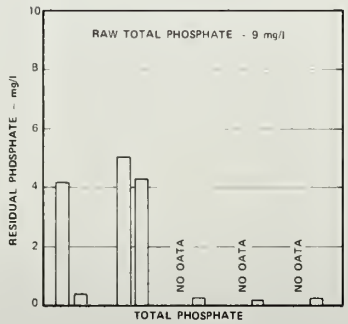












LEGEND

CONV. A.S. = CONVENTIONAL AIR ACTIVATED SLUDGE

- FIRST BAR IS SECONDARY CLARIFIER EFFLUENT
- SECOND BAR IS SECONDARY CLARIFIER EFFLUENT + ALUM COAGULATION, AND SETTLING + FILTRATION + CARBON ADSORPTION

HPO A.S = HIGH PURITY OXYGEN ACTIVATED SLUDGE

- FIRST BAR IS SECONDARY CLARIFIER EFFLUENT
- SECOND BAR IS SECONDARY CLARIFIER + FILTRATION + CARBON ADSORPTION

$FeCl_3$ P/C = FERRIC CHLORIDE PHYSICAL/CHEMICAL TREATMENT

- FIRST BAR IS CLARIFIER EFFLUENT
- SECOND BAR IS CLARIFIER + FILTRATION + CARBON ADSORPTION

$FeCl_3$ + LIME P/C = FERRIC CHLORIDE PLUS LIME PHYSICAL/ CHEMICAL TREATMENT

- FIRST BAR IS LIME CLARIFIER EFFLUENT + TWO-STAGE RECARBONATION
- SECOND BAR IS RECARBONATION EFFLUENT + FILTRATION + CARBON ADSORPTION

FIGURE 6

GRAPHICAL REMOVAL SUMMARY SOUTHEAST TEST

- Percent BOD removal
- Residual BOD
- Total Chromium
- Oil and Grease
- Total Phosphate

The applicable discharge standard for each constituent is also shown.

Figure 5 was prepared to show general process requirements and comparative costs to meet each of the applicable discharge standards, with the exception of the total chromium standard. None of the processes tested at any of the treatment plants could meet the 0.005 mg/l total chromium standard.

Conclusions

The conclusions which follow are subdivided into the following categories:

- General
- North Point-Southeast
- Richmond-Sunset

SUMMARY AND CONCLUSIONS

A. General

1. A stringent rigorously enforced industrial waste discharge control program is essential to the satisfactory operation of any treatment process.

2. None of the processes tested can meet the SWRCB requirements for effluent total chromium concentration of not more than 0.005 mg/l whether treating Southeast, North Point or Richmond-Sunset sewage.

3. Alum, ferric chloride, and lime are equally satisfactory coagulants in terms of those effluent constituents included in EPA and SWRCB standards.

4. The cationic polymer Magnifloc 509-C is not effective in removing soluble phosphorous.

5. An anionic polymer coagulant aid is essential to satisfactory floc formation. The anionic polymer should be added at a point at least 3 minutes downstream from the primary coagulant to allow adequate reaction time.

6. Magnifloc 509-C, when diluted with water, will separate in storage.

7. The high dose of ferric chloride required to coagulate the San Francisco sewages will have a major adverse effect on anaerobic digestion of the sludge produced. There is some indication of a potential cumulative toxic effect. Additional study is necessary to quantify this effect.

8. The high dose of alum required to coagulate the San Francisco sewages will have a major adverse effect on anaerobic digestion of the sludge produced. Additional study is necessary to quantify this effect.

9. The permissible sedimentation basin overflow rates to produce effluents meeting the SWRCB ocean discharge requirements and to produce a filterable effluent with various coagulants are:

	Overflow Rate gpd/sq ft	
Coagulant	Filterable Effluent	Effluent Meeting SWRCB
Alum	*1200	1600
Ferric	*1200	1600
Magnifloc 509-C	*1600	2000

* Reduced to 1000 gpd/sq ft for North Point-Southeast estimates because of density change upsets.

10. For filtration to be practical, sedimentation basin effluent must contain no more than a trace of settleable solids and should have a turbidity of less than 15 FTU.

11. The use of the cationic polymer Magnifloc 509-C has little or no effect on the pH of the sewage and does not require the addition of chemicals for alkalinity control.

12. Alum and Magnifloc 509-C can be used in combination as primary coagulants. However, the combination offers no advantage over the two coagulants used separately and adds to the complexity of chemical feed control.

13. The use of Magnifloc 509-C for coagulation of rain diluted sewage requires a small percentage recycle of previously settled solids for efficient coagulation.

14. Automatic control of coagulant dosage is essential to the production of a filterable settled effluent.

15. The addition of coagulant chemicals to wastewater creates a potential foaming problem that must be considered in treatment plant design.

16. In the course of this project, several areas were identified where ongoing studies are needed:

- o Anaerobic digestion of chemically treated sludges.
- o Improved laboratory procedures for tests of oil and grease, floatables, and COD for samples of high salinity.
- o A satisfactory method of determining and controlling the proper coagulant dose for storm water-diluted combined sewage. Presently available technology is inadequate to follow the rapid changes in coagulant requirements.

This is particularly significant in relation to the San Francisco Master Plan proposal for chemical coagulation of storm water.

- o The value of or need for mechanical flocculation in the treatment of rain-diluted sewage.

B. North Point-Southeast

1. At present and for the foreseeable future there appears to be no practical potential for reuse of the effluents from plants treating the North Point and Southeast sewages due to the high dissolved solids in the sewage and the cost of reducing them to levels necessary for most types of reuse.

2. The development of a means of reducing the rate of density changes in the North Point and Southeast sewages is a prerequisite to consideration of chemical coagulation-filtration processes. The reduction must be sufficient to prevent upsets of the sedimentation basins and the resulting impractically short filter runs.

3. Even without control of sewage density variations, properly designed coagulation and sedimentation facilities can treat the blended North Point-Southeast sewage to produce an effluent meeting the current SWRCB Ocean Discharge requirements with the exception of the standard for chromium. (The SWRCB Discharge Requirements do not include BOD removal.)

4. Tertiary physical/chemical treatment of combined North Point-Southeast sewage would be only marginally successful in meeting the EPA 30 mg/l effluent BOD requirement.

5. The high magnesium concentration in the North Point and Southeast sewages makes lime coagulation to pH 11.2 an easily controlled process producing an effluent of excellent clarity. However, because of this high magnesium concentration, sludge dewatering and thickening are extremely difficult. It is not economically practical to recalcine the sludge leaving no practical method of sludge disposal.

6. Limited data available from observations of the performance of the lime clarifier during periods of storm water runoff indicate that lime coagulation in the absence of saltwater would be difficult and might require the addition of a supplemental coagulant. The magnesium present in the saltwater serves as a coagulant.

7. With control of the North Point-Southeast sewage density variations, coagulation with alum or ferric chloride followed by filtration and activated carbon can produce an effluent marginally meeting the requirements of the EPA and the SWRCB Tentative Bay Discharge Standards with the exception of the chromium standard.

8. While control of salinity induced density changes is essential to satisfactory physical/chemical treatment of the North Point-Southeast sewage, plant scale testing at the Richmond-Sunset plant

in addition to bench scale testing indicates that the elimination of saltwater from these sewages will make it difficult to properly control the coagulant dose during periods when the sewage is diluted with rain water. The presence of rain water narrows the band of permissible coagulant doseage.

9. The intentional addition of San Francisco Bay water to the North Point and Southeast sewages plus the intruded saltwater broadens the range of chemical dosages which will provide satisfactory coagulation. In other words, with the addition of saltwater a given chemical dosage will provide satisfactory coagulation over a much wider range of raw sewage conditions than would be possible without the added saltwater. This accounts for the success which has been experienced in operating the North Point and Southeast plants with relatively low doses of ferric chloride.

10. When treating the blended North Point-Southeast sewage, either the conventional activated sludge process or the high purity oxygen activated sludge process can produce an effluent meeting the EPA requirements. Both processes would require the addition of filtration to consistently meet the tentative Bay discharge requirement for effluent suspended solids not exceeding 15 mg/l.

11. Comparing the two biological systems tested, the conventional air activated sludge process produces

an effluent of higher pH, lower turbidity, and lower metals concentration than does the high purity oxygen activated sludge. The high purity oxygen activated sludge is the more stable process and produces a more compact sludge.

12. The relative capital, operation, maintenance, and repair (OM&R), and present value costs of primary physical/chemical (PP/C) and activated sludge (A/S) treatment necessary to meet the SWRCB Ocean Discharge Requirements are:

	PP/C	A/S
Capital Cost	$42,760,000	$58,280,000
OM&R	6,410,000	3,910,000
Total Present Value	97,140,000	86,530,000

13. The relative costs of tertiary physical/chemical (TP/C) and activated sludge treatment necessary to meet the EPA discharge requirements are:

	T P/C	A/S
Capital Cost	$94,120,000	$58,280,000
OM&R	9,890,000	3,910,000
Total Present Value	173,630,000	86,530,000

14. The relative costs of tertiary physical/chemical and activated sludge treatment necessary to meet the SWRCB Tentative Bay Discharge Requirements are:

	TP/C	A/S
Capital Cost	$94,200,000	$76,330,000
OM&R	9,890,000	4,560,000
Total Present Value	173,630,000	110,390,000

C. Richmond-Sunset

1. It is doubtful if tertiary physical/chemical treatment of Richmond-Sunset sewage can consistently meet the EPA 30 mg/l effluent BOD requirement.

2. The limited area of the present Richmond-Sunset plant site makes it impractical to consider the construction of tertiary physical/chemical treatment units within the boundaries of the site.

3. The present Richmond-Sunset site will accommodate the construction of facilities sufficient to provide primary physical/chemical treatment using either alum or Magnifloc 509-C as the primary coagulant.

4. Primary physical/chemical treatment of Richmond-Sunset sewage can produce an effluent meeting

the SWRCB Ocean Discharge Requirements. When combined with an activated sludge effluent from a North Point-Southeast plant the resulting effluent might marginally meet the EPA Discharge Requirements.

5. A high purity oxygen activated sludge expansion of the Richmond-Sunset plant could be accomplished with the acquisition of approximately 10 acres (4 hectares) of additional adjacent land.

6. Primary physical/chemical treatment of Richmond-Sunset sewage with Magnifloc 509-C will require the addition of chemical feed facilities, sedimentation basins, sludge thickeners, and vacuum filters. With alum coagulation, an additional digester will also be needed.

7. While activated sludge processes were not tested on Richmond-Sunset sewage, the results of the North Point-Southeast tests fully demonstrate the ability of this process to satisfactorily treat Richmond-Sunset sewage to consistently meet the EPA requirements.

8. The effluent from an activated sludge Richmond-Sunset treatment plant should be suitable for irrigation since salinity is not a problem in the Richmond-Sunset sewage.

9. The relative costs of the three treatment processes considered practical alternatives for treatment of Richmond-Sunset sewage are:

	Process		
	Alum PP/C	509-C PP/C	HPO A/S
Capital Cost	$ 6,690,000	$ 4,830,000	$14,590,000
OM&R Cost	1,670,000	2,760,000	1,040,000
Total Present Value	21,550,000	30,330,000	22,270,000
Effluent Requirement Capability	SWRCB	SWRCB	EPA & SWRCB

10. Ferric chloride is not considered a practical coagulant for Richmond-Sunset sewage because of the narrow range of satisfactory dosage and the potential sludge digestion problems.

SECTION I

SECTION I

INTRODUCTION

The City and County of San Francisco is served by a combined sewer system handling both domestic sewage and stormwater. The sewage is treated in three primary sewage treatment plants located as shown on Figure 1-1. The largest of these is the North Point plant, which, under dry weather conditions, treats an average flow of about 65 mgd. (2.85 cu m/sec). The Southeast plant treats 20 mgd (0.88 cu m/sec) and the Richmond-Sunset plant treats approximately 25 mgd (1.10 cu m/sec). The North Point plant serves an area largely occupied by commercial and multiunit residential buildings. The Richmond-Sunset plant treats primarily residential sewage although there are several large hospitals in the collection area. The Southeast plant treats sewage from an area which is occupied largely by light industries. All industrial wastes are treated in the San Francisco treatment plants. At the Southeast and North Point plants the sewage is coagulated with a low dose of ferric chloride to aid suspended solids removal. An anionic polymer at a fractional mg/l dose and saltwater from the bay in an amount equal to 5 to 10 percent of the raw sewage flow are also added as an aid to coagulation.

Since the bulk of the industry in San Francisco is located in the area served by the Southeast plant, the sewage entering this plant is much stronger and subject to much wider variations in constituent concentrations than is normal in metropolitan sewage.

Each of the plants is a typical primary sewage treatment plant having facilities for chlorination, screening, grit removal, and sedimentation. The North Point plant has no facilities for sludge treatment other than sludge pumps which are used to transport the sludge from the North Point plant approximately 6 miles (9.7 km) through a 10-inch (25.4 cm) line to the Southeast plant. At the Southeast plant, facilities are available for thickening of the sludge, anaerobic digestion, elutriation, and vacuum filtration. The sludge is ultimately disposed of by hauling to a landfill. As a result of handling all North Point sludge at the Southeast plant, the amount of recycle from the various sludge treatment processes at Southeast is abnormally high and has historically caused problems in the operation of the Southeast plant.

At the Richmond-Sunset plant, provisions are made for thickening, anaerobic digestion, elutriation, and vacuum filtration of the sludge produced at that plant.

Because the sewer system is a combined sewer system, there are many overflow structures along the waterfront where stormwaters in excess of the treatment plant capacities are periodically released. Problems are continually encountered with the tide gates on these outlets. These gates are designed to open automatically to release stormwater and to close during periods of normal sewage flow thus preventing the entrance of saltwater into the sewer system. It has long been recognized that these gates frequently fail in this function and do permit saltwater to enter the sewer system. In addition, many sewers are laid below the water level in San Francisco Bay. These sewers are old and there is evidence that in certain areas they leak rather badly. These leaks serve

as another source for the infiltration of seawater into the sewers. The San Francisco Department of Public Works is currently conducting an extensive study of the sources of infiltration and inflow into the San Francisco sewer system.

In 1970 San Francisco undertook to improve the quality of effluent produced by the North Point and Southeast plants by adding facilities to permit coagulation of the sewage with ferric chloride. A considerable amount of experimentation, both in relation to ferric chloride dosages and the use of various polymers, was accomplished in an attempt to establish a dosage regime which would produce the desired results. During the course of this work, it was determined that the addition to the sewage of approximately 5 percent saltwater from the bay in addition to that which was already present in the sewage markedly improved the effectiveness of the ferric chloride. Based on these findings, later confirmed in plant scale tests, it has been the practice to add saltwater to the influents at North Point and Southeast during periods when coagulants are being used.

In September 1971 the San Francisco Department of Public Works completed the "San Francisco Master Plan for Wastewater Management." This plan resulted from exhaustive studies of alternative methods of solving both the problem of adequately treating the dry weather sewage flow as well as adequately handling the combined sewage flow. In brief, the plan provides for the construction of numerous combined sewage retention basins located both along the bay front and in the upper reaches of the sewer system. These basins are designed to hold up the peak combined sewage flows for later release for treatment after the

storm has passed. Retention and release of combined sewage from the retention basins is to be controlled by a computer program related to an extensive area-wide rainfall monitoring system.

The plan as originally conceived contemplated the construction of a single treatment plant in the vicinity of Lake Merced to treat all San Francisco sewage. This plant was to have a dry weather capacity of approximately 250 mgd (946,250 cu m/day) and a wet weather capacity of 1,000 mgd (3,785,000 cu m/day). The degree of treatment proposed for the dry weather flow was to be dependent upon the ultimate point of disposal of the effluent or the ultimate use of the effluent. In October 1973, the San Francisco Board of Supervisors gave tentative approval to a modified version of the Master Plan which includes the construction of facilities at the site of the Southeast plant for treatment of the combined North Point and Southeast sewages. Also contemplated is the expansion of treatment facilities at the Richmond-Sunset plant sufficient to meet the requirements for disposal to the ocean.

The effluent from the combined North Point-Southeast plant could be discharged either to the bay or to the ocean. If the decision as to the point of effluent disposal is to be based solely on economics, then the relative requirements for effluent quality for discharge to the bay and to the ocean are of primary concern. At the present time, the requirements of the California State Water Resources Control Board (SWRCB) for the discharge of effluent to the ocean does not include a requirement for BOD removal. The tentative San Francisco Bay Regional Water Quality Board (RWQCB) requirements for discharge to the bay include not only a requirement for 85 percent

BOD removal, but also a requirement that the suspended solids level not exceed 15 mg/l. Overshadowing these requirements is the requirement of the United States Environmental Protection Administration (EPA) requiring 85 percent BOD removal - whether the effluent is discharged to the bay or to the ocean.

It is obvious that the standards finally selected for enforcement will play a predominant role in determining the cost of facilities necessary to treat the San Francisco sewage. Since the details of these requirements have changed markedly during the course of this study and are not yet firmly established, the study reported herein was structured to consider all presently anticipated eventualities.

PROJECT GOAL

The ultimate project goal was to identify or develop sufficient data to statistically support design criteria for a series of wastewater treatment process "building blocks." These building blocks were to make it possible to evaluate incremental construction of wastewater treatment facilities that were to be capable of producing increasing degrees of treatment to provide effluent suitable for:

- Ocean discharge
- Bay discharge
- Irrigation use
- Ground Water recharge
- Industrial use

The building block concept was considered desirable as a means of avoiding obsolescence of initially constructed facilities as treatment requirements become more stringent either because of legal requirements or the improved economics of wastewater reuse.

PROJECT WORK PLAN AND BUDGET SUMMARY

The project was originally conceived as a relatively intense crash program with an interim report initially scheduled for completion by 1 June 1973. As the details of the project developed, the desirability of adjusting the scope of the project and extending the time for completion was recognized. Additional funding for the project was approved by the SWRCB and the final draft completion time was extended to 1 June 1974, with an interim draft report scheduled for 15 December 1973. It was originally planned that the interim report would provide tentative design parameters for a treatment plant suitable for treating the combined North Point-Southeast sewage based on data collected on pilot plant studies on the Southeast sewage. It was assumed that these parameters could give the San Francisco Department of Public Works an opportunity to get an early start on preliminary designs for treatment facilities. However, the bench scale program, which was undertaken in May of 1973, gave an indication of serious problems in the planned treatment of the Southeast sewage. These difficulties were soon confirmed by the operation of the pilot facilities on the Southeast sewage. It was recognized that any extrapolation from the Southeast data to the treatment of the blended North Point-Southeast sewages would be hazardous.

It was initially contemplated that the pilot plant would be set up first at the Southeast plant where it would be

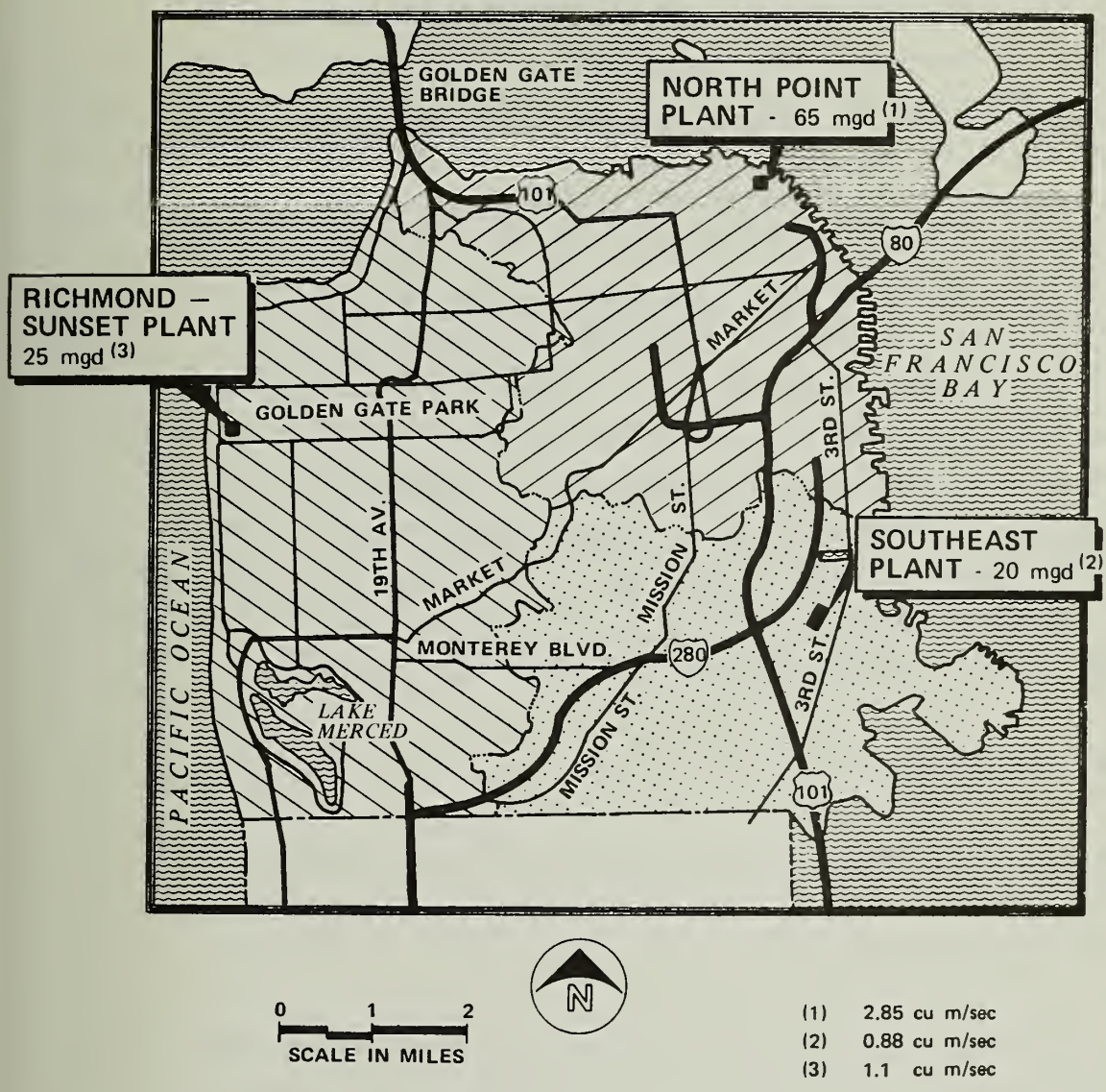


FIGURE 1-1

SAN FRANCISCO
WATER POLLUTION CONTROL PLANT
LOCATIONS AND SERVICE AREAS

operated for approximately 30 days, following which it would be moved to the North Point plant and then to the Richmond-Sunset plant for similar operating periods. The difficulties encountered in treating Southeast sewage and the erratic nature of this sewage coupled with the City's plan to ultimately treat the combined North Point and Southeast sewages led to the development of a plan which permitted transporting North Point sewage to the pilot plant at the Southeast plant where it was blended with the Southeast sewage. Tests were then conducted on this blended sewage simulating the treatment problems which will ultimately be encountered in the proposed treatment facilities. A small section of the pilot plant was moved to Richmond-Sunset where pilot and plant scale tests were conducted on various physical/chemical processes.

PROJECT BUDGET

Table 1-1 is the project budget as finally modified.

REPORT ORGANIZATION

The report is organized in accordance with the chronology of the tasks undertaken. The initial effort was the preparation of a work plan which was redone after the scope of the project was expanded in March 1973. To assure that the study did not duplicate work which had been accomplished by others, an extensive investigation was made of available data related to constituent removal by various candidate processes. This was carried on with a program to characterize the influent sewages at the three San Francisco treatment plants in terms of over 100 constituents. Based on these investigations, final selection was made of processes to

TABLE 1-1

PROJECT BUDGET

TASK 1	Development of an Operations and Control Budget Work Plan	$ 35,000
TASK 2	Review, Complete and Update 1970 Constitutent Base Line Data. Establish Base Line Problem Constitutents	83,000
TASK 3	Review of Industrial Waste Survey Data and Confirm Feasibility of Source Control for Candidate Constitutents	10,000
TASK 4	Treatment Process Pilot Work	912,000
TASK 5	Data Collection, Reduction and Reports	146,000
TASK 6	Preliminary Plant Layouts	44,000
	TOTAL	$1,230,000

be pilot tested and the construction of the pilot plant was undertaken. Concurrently with construction, extensive bench scale tests were performed to develop operating parameters for the pilot test program. Following completion of the pilot plant, tests were conducted on the Southeast sewage followed by testing of blended North Point-Southeast sewage and finally pilot and full scale plant tests were conducted on the Richmond-Sunset sewage.

Throughout the report constituent data have been organized in the following categories:

Metals, chemical, nutrients, radioactive, physical, bioassays, chlorinated hydrocarbons.

TREATMENT REQUIREMENTS

While initially there was a major interest in the potential for reuse of the San Francisco treatment plant effluents for such benefits as irrigation and ground water recharge, data from the influent characterization program produced evidence of total dissolved solids and specifically of chloride concentrations so high as to require some type of deionization treatment before reuse of either the North Point or the Southeast sewages would be practical for these purposes. Present day costs for deionization are approximately $400 to $500 per million gallons (3785 cu m). For this reason, little further attention was given to these possibilities, and the selection of candidate treatment processes was concentrated on the requirements of the various regulatory agencies for the production of an effluent suitable for discharge to either the Pacific Ocean or San Francisco Bay. In Table 1-2 are shown the current requirements of the EPA the SWRCB and the RWQCB for discharge to the ocean and bay.

TABLE 1-2
DISCHARGE REQUIREMENTS

CONSTITUENT		DISCHARGE REQUIREMENTS					
		OCEAN[1]		EPA[2]		BAY[3]	
		50%	10%	30-day	7-day	50%	10%
PHYSICAL							
Floatables	mg/l	1.0	2.0	NONE		NONE	
Grease and Oil	mg/l	10	15	NONE		5	
Suspended Matter	mg/l	50	75	30 85%[4]	45	15	
Settleable Matter	ml/l/hr	.1	.2	NONE		.1	
Turbidity	JTU	50	75	NONE		10	
CHEMICAL:							
BOD_5	mg/l	NONE		30	45	–	–
	%			85%		85%	
Arsenic	mg/l	.01	.02	NONE		.01	.02
Cadmium	mg/l	.02	.03	NONE		.02	.03
Total Chromium	mg/l	.005	.01	NONE		.005	.01
Copper	mg/l	.2	.3	NONE		.2	.3
Lead	mg/l	.1	.2	NONE		.1	.2
Mercury	mg/l	.001	.002	NONE		.001	.002
Nickel	mg/l	.1	.2	NONE		.1	.2
Silver	mg/l	.02	.04	NONE		.02	.04
Zinc	mg/l	.3	.5	NONE		.3	.5
Cyanide	mg/l	.1	.2	NONE		.1	.2
Phenolic	mg/l	.5	1.0	NONE		.5	1.0
Total Cl_2 Residual	mg/l	1.0	2.0	NONE		1.0	2.0
Ammonia (N)	mg/l	40	60	NONE		40	60
TICH	mg/l	.002	.004	NONE		.002	.004
pH	–	6.0-9.0		6.0-9.0		6.5-8.5	
TOXICITY:	Various	1.5 tu	2.0 tu	NONE		40 ml/l (RT)	

1. California State Water Resources Control Board – "Water Quality Control Plan – Ocean Waters of California" July 6, 1972.
2. Environmental Protection Agency – Federal Register Vol. 3S, No. 159, Part II, "Water Programs – Secondary Treatment Information".
3. California Regional Water Quality Control Board – San Francisco Bay Regions Basin Plan – Tentative Water Quality Objectives and Waste Discharge Prohibitions–Dec. 19, 1972.
4. The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 15 percent of the arithmetic mean of the values for influent samples collected at approximately the same times during the same period (85 percent removal).

Coliform bacteriological standards were not included in the project studies because of the vast amount of information already available on sterilization.

SECTION II

SECTION II
EXISTING DATA REVIEW

PURPOSE OF DATA COLLECTION

At the inception of this project in 1972, probable effluent requirements for discharge to the ocean or to San Francisco Bay were even less clearly defined than they are at the present time. Serious consideration of limitations on levels of heavy metals and pesticides was only rumored at that time. Information in the literature as to the ability of various treatment processes to remove heavy metals, pesticides, and materials of these types was very limited. Preliminary data collected in previous years had indicated levels of these materials in the San Francisco raw sewages which potentially could cause problems depending upon effluent discharge requirements. All of these things were considerations in the initial project development.

It was believed that an investigation of current research would disclose unpublished data which could serve to limit the required scope of the San Francisco Pilot Plant project. With this in mind, an extensive data collection program was undertaken. It was specified that the data collected should be "raw data" rather than data which had been summarized or averaged. It was further specified that these data should be statistically treated in order to indicate the relative stability of processes under consideration. Most of the investigators who were contacted were extremely cooperative in making their data available. Sources of data and processes for which data were obtained are indicated on Figures 2-1 and 2-2.

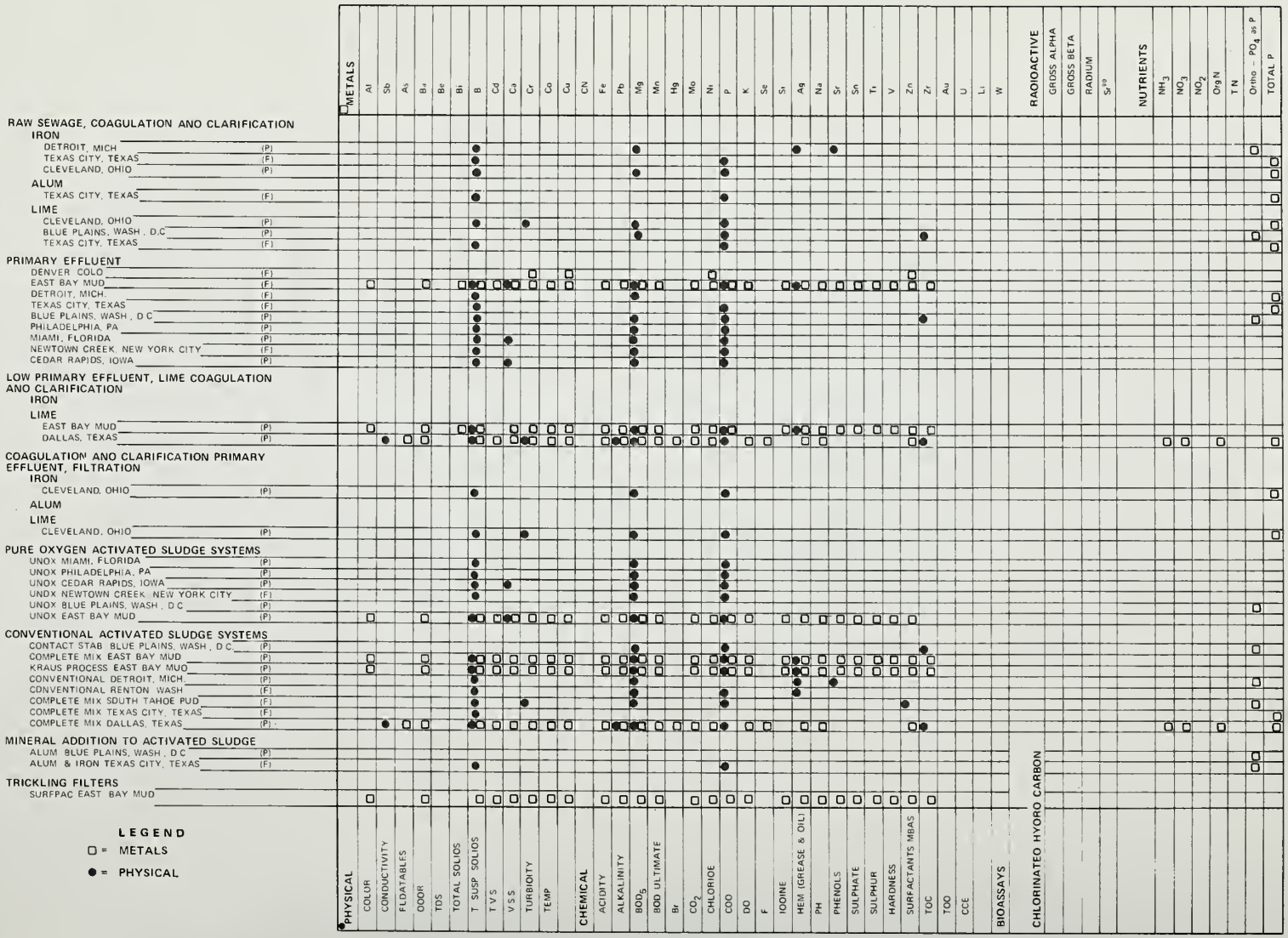


FIGURE 2-1
SOURCES OF CONSTITUENT REMOVAL DATA

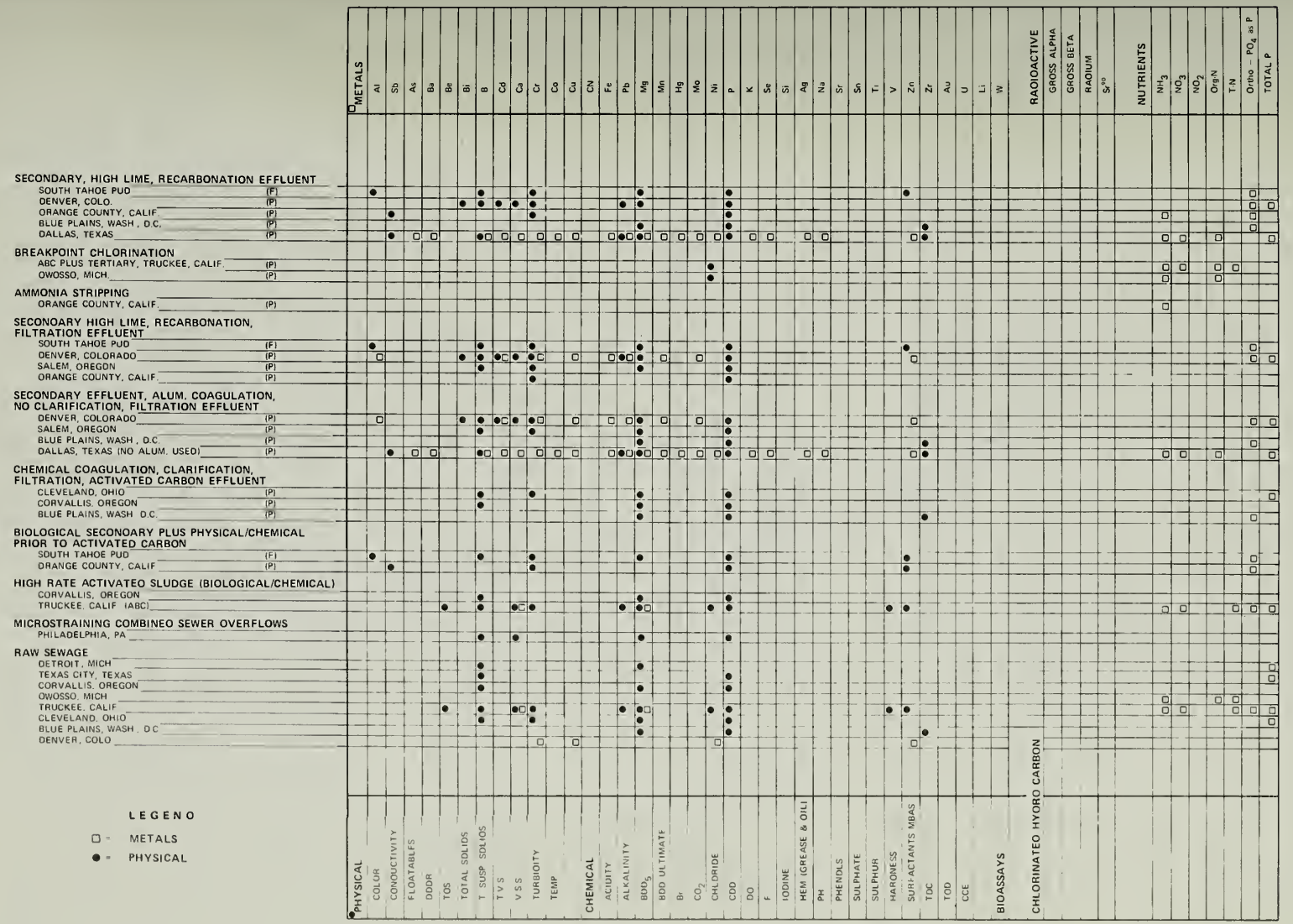


FIGURE 2-2
SOURCES OF CONSTITUENT REMOVAL DATA

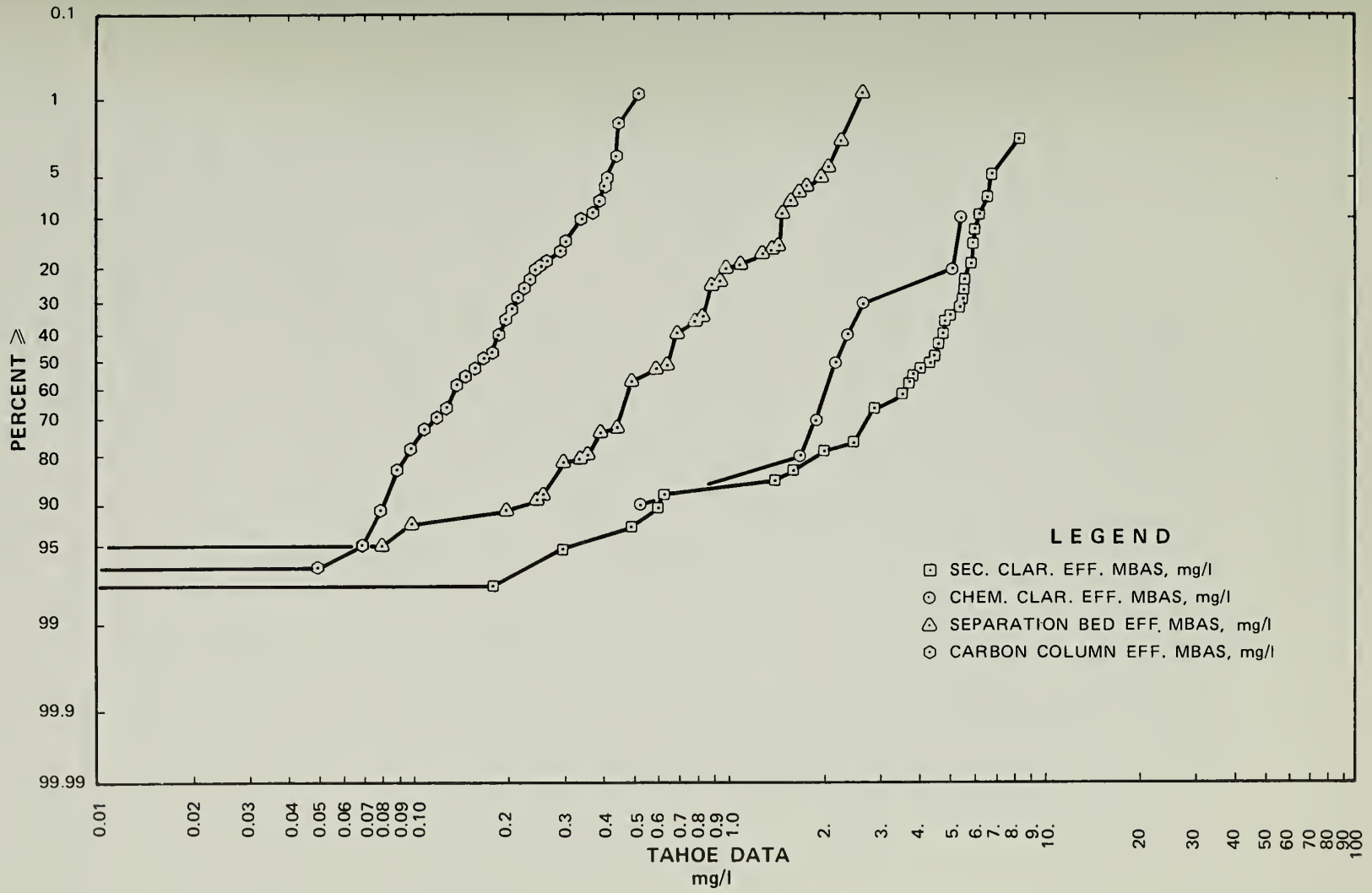
SOURCES AND VOLUME OF DATA

The original hope was that the data from various research projects and actual plant operations could be assembled by process and constituent removal and statistically analyzed. After collecting several thousand data points, we found that there was no practical method of combining data from one source with that from another because of the paucity of data related to any particular process. Essentially all of the available data included more than one process, and seldom were the processes the same or even similar. For these reasons, data were generally collected into 9 categories. These were:

Conventional Activated Sludge
Pure Oxygen Activated Sludge
Biological Treatment plus Direct Filtration
Biological Treatment plus Physical/Chemical Treatment
Low Ferric Chloride
Coagulation/Carbon Adsorption

Lime Physical/Chemical Treatment
Nitrogen Removal
Alum or High Ferric Physical/Chemical Treatment

The data from each source and for each constituent were therefore plotted separately. This resulted in the production of over 400 statistical plots similar to those shown in Figures 2-3 and 2-4. Several attempts were made to develop a method of summarizing these data, however, their variety made this impractical and it was therefore decided to simply catalog the individual data plots. This was done and the material is on file in the San Francisco Department of Public Works Offices.


PERCENT ⩾
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40
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90
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99
99.9
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2.
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4.
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6.
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8.
9.
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30
40
50
60
70
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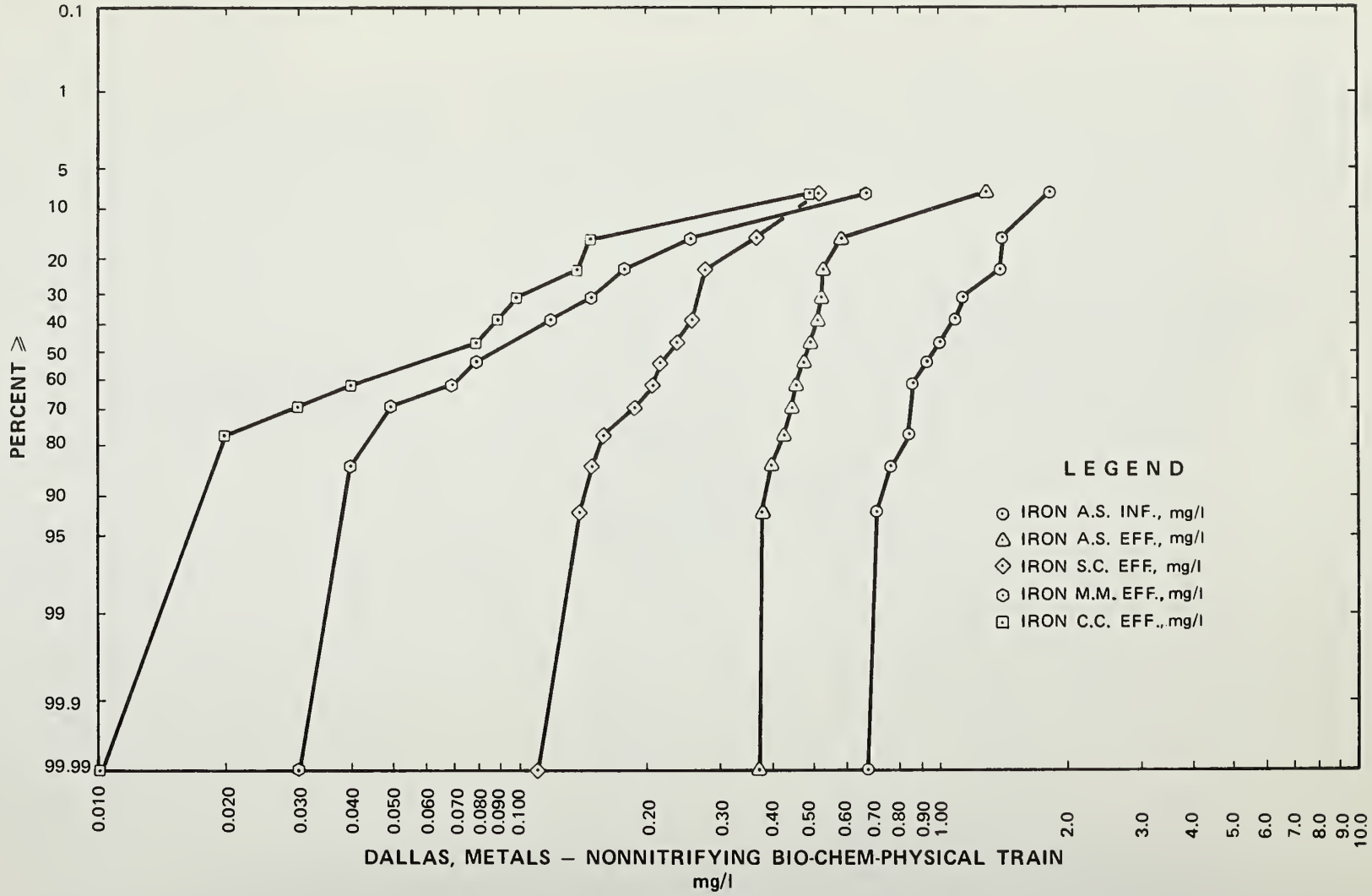
90
100
TAHOE DATA
mg/l
LEGEND
SEC. CLAR. EFF. MBAS, mg/l
CHEM. CLAR. EFF. MBAS, mg/l
SEPARATION BED EFF. MBAS, mg/l
CARBON COLUMN EFF. MBAS, mg/l

FIGURE 2-3


PERCENT ≥
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1.00
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4.0
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6.0
7.0
8.0
9.0
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DALLAS, METALS – NONNITRIFYING BIO-CHEM-PHYSICAL TRAIN
mg/l
LEGEND
IRON A.S. INF., mg/l
IRON A.S. EFF., mg/l
IRON S.C. EFF., mg/l
IRON M.M. EFF., mg/l
IRON C.C. EFF., mg/l

FIGURE 2-4

A review of these data in the light of the influent characterization program indicated that so long as the constituents of concern in the San Francisco sewages remained approximately at the measured levels, any of the treatment processes under consideration could be developed to produce effluents meeting all of the anticipated requirements except it appeared that none of the processes would meet the requirement of 0.005 mg/l of chromium. The review also pointed out the potential inability of the strictly physical/chemical process trains to meet the BOD removal requirements.

It had been originally hoped that data from other sources could be statistically integrated with data from the San Francisco Pilot Plant Study and thereby make possible the development of statistically meaningful answers as to constituent removal without actual pilot plant operation and analyses. The fact that it was impossible to combine data from various sources made it necessary to abandon this hope and to develop data relative to the San Francisco sewages based solely on the testing of these sewages.

SECTION III

SECTION III
PILOT PLANT DESIGN

SOUTHEAST PILOT PLANT

Process Design

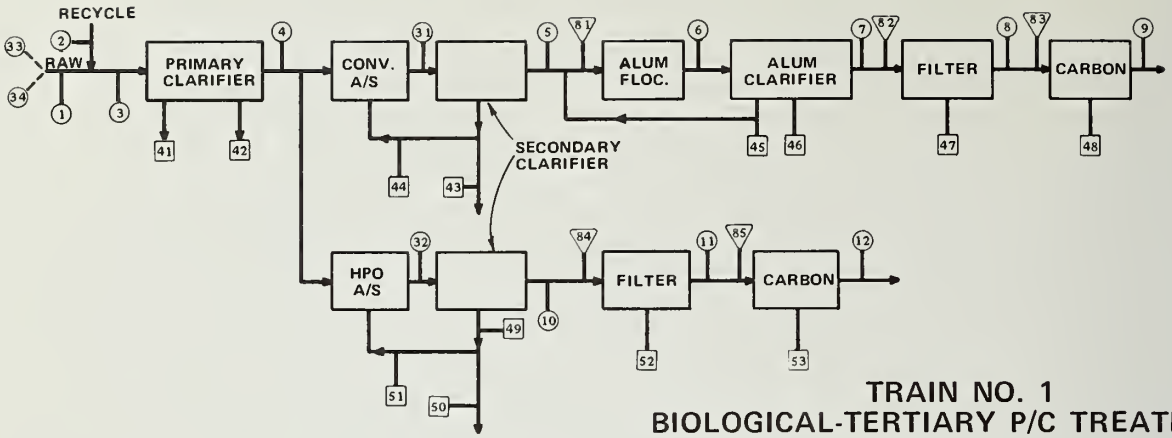
The process flow sheet for the pilot plant is shown on Figure 3-1. The pilot plant was divided into three process trains which produced five different effluents. The design criteria are shown on Figures 3-2 through 3-6. Figure 3-7 is a site plan of the pilot plant. The location of the photographs accompanying this section are also shown on the site plan. Figures 3-8 and 3-9 are general views of the pilot plant.

Train No. 1-

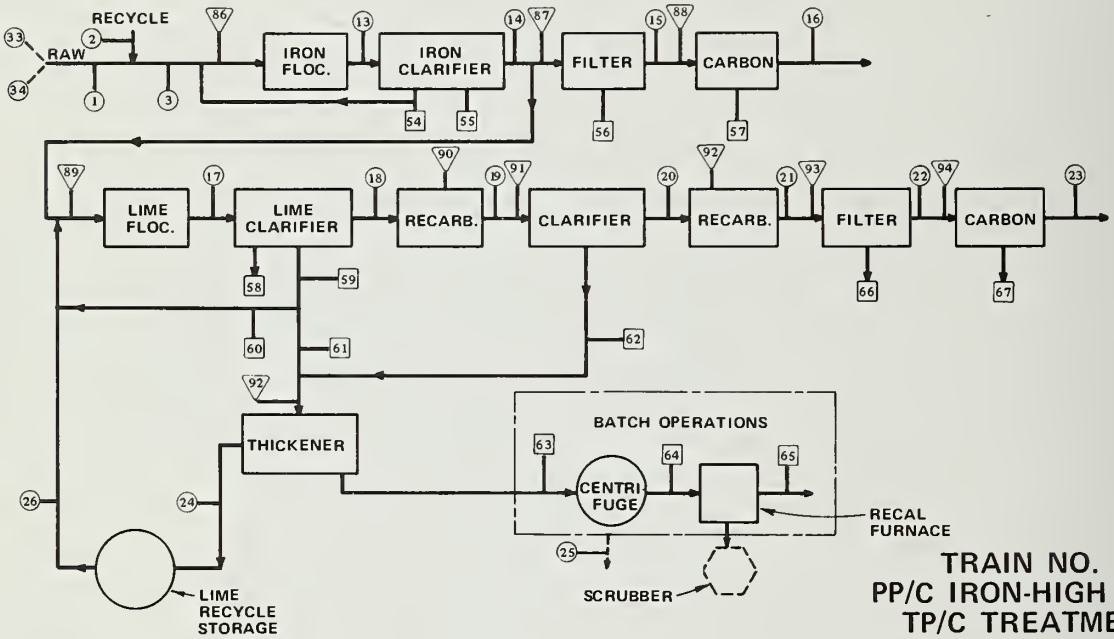
Train No. 1 consisted of a screening and degritting, primary sedimentation and equal division of the primary effluent to conventional air and high purity oxygen activated sludge processes. The secondary clarifier effluents of the two biological processes were processed in separate ways: one was directed to physical/chemical treatment with chemical coagulation and clarification followed by filtration and activated carbon adsorption, while the other biological effluent was processed by direct filtration and activated carbon adsorption.

Train No. 2-

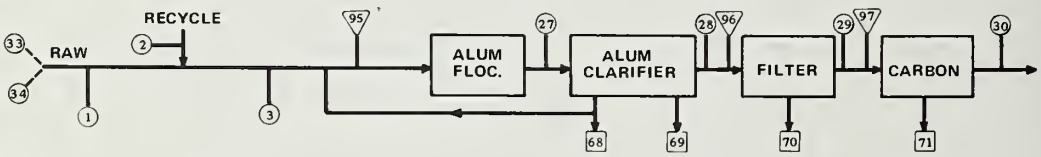
Train No. 2 consisted of screening and degritting followed by a ferric chloride coagulation and clarification process, the effluent of which was divided into two portions: one



TRAIN NO. 1
BIOLOGICAL-TERTIARY P/C TREATMENT



TRAIN NO. 2
PP/C IRON-HIGH LIME
TP/C TREATMENT



TRAIN NO. 3
TERTIARY PHYSICAL/CHEMICAL TREATMENT

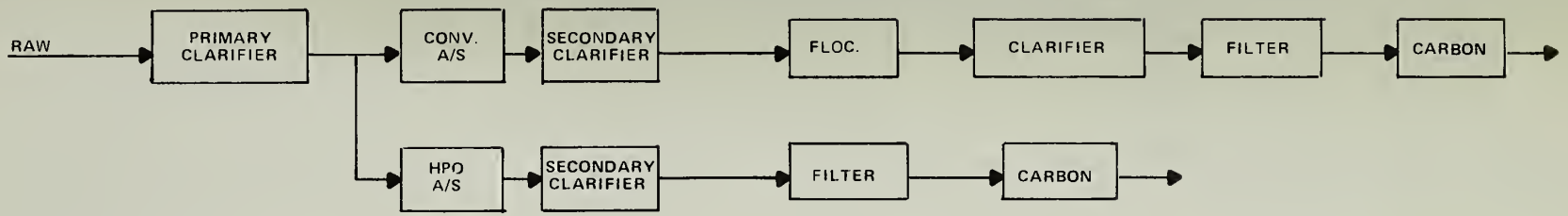
NOTES:

(1)	TO (34)	LIQUID STREAM DATA POINTS
[41]	TO [71]	SOLID OR WASTE DATA POINTS
▽81	TO ▽97	CHEMICAL ADDITION POINTS
– – – –		INDICATES NP + SE
(33)		SE RAW
(34)		NP RAW

FIGURE 3-1

SOUTHEAST PILOT PLANT
PROCESS TRAINS AND DATA COLLECTION POINTS

TRAIN NO. 1 BIOLOGICAL – TERTIARY P/C TREATMENT



DESIGN CRITERIA	CONVENTIONAL PRIMARY				CONVENTIONAL ACT. SLUDGE			HPO ACT. SLUDGE			SECONDARY CLARIFIERS			RAPID MIX			
DIAMETER, FT.[2]	9				–			–			6			–			
SWD[3] DEPTH, FT	8.83				8'			5.2			8.33			–			
LIQUID DEPTH, FT.	10.0				8'			5.2			9.50			–			
SURFACE AREA, SF[2]	63.78				–			–			28.6			–			
VOLUME, GAL.	5044[4]				4338			1600			2376			13.4			
STAGE VOLUME, GAL.	–				–			400			–			–			
TYPE	CONVENTIONAL				COMPLETE MIX – AIR			OXYGEN			CONVENTIONAL			–			
EFF. 8ED DEPTH, FT	–				–			–			–			–			
CARBON, L8S.	–				–			–			–			–			
PERCENT OF DESIGN	75	100	150	MAX.	75	100	150	75	100	150	75	100	150	75	100	150	MAX.
FLOW, GPM	33	44.2	66.3	79.5	10.3	13.8	20.7	10.3	13.7	20.5	10.2	13.6	20.4	6.6	8.9	13.4	16
DETENTION TIME, HRS.	2.5	1.9	1.3	1.1	6.9[5]	5.2[5]	3.5[5]	2.6[5]	1.9[5]	1.3[5]	3.9	2.9	1.9	2	1.5	1	.8
OVERFLOW, GPD/SF	750	1000	1500	1795	–	–	–	–	–	–	514	684	1027	–	–	–	–
HYDRAULIC LOADING, GPM/SF	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
VELOCITY, FPM	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
MIXING FORCE, G, FPS/F	–	–	–		–	–	–	–	–	–	–	–	–	300	300	300	300
CONTACT TIME, MIN.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

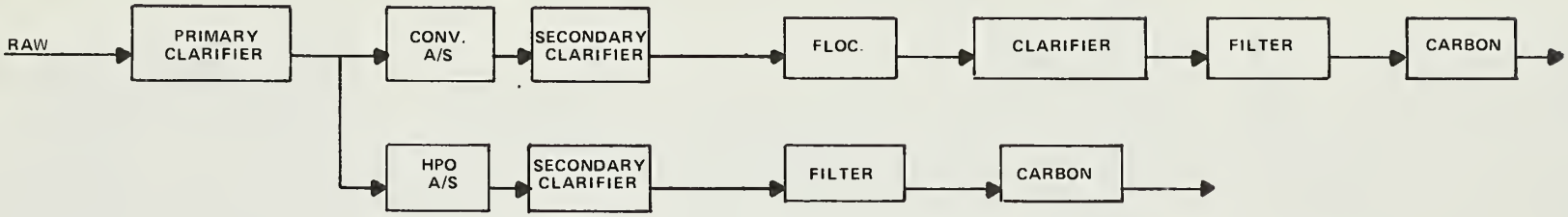
(1) MINUTES
(2) EFFECTIVE DIAMETER OR AREA (DEDUCTS AREA OCCUPIED BY CLARIFIER FEED WELL AND LAUNDER)
(3) SIDE WATER DEPTH
(4) SIDE WATER VOLUME MINUS FEED WELL
(5) 8ASED ON O

METRIC FORMULAS

FT	=	(x 0.3048 m)	GPD/SF	=	(x 0.0408 $m^3/m^2/d$)
SF	=	(x 0.0929 sq.m.)	GPM/SF	=	(x 40.7 $1/min/m^2$
GAL	=	(x 3.785 l)	FPM	=	(x 0.3048 m/min)
LBS	=	(x 0.454 kg)	FPS/F	=	(x 1.0 m/sec/m)
GPM	=	(x 0.0631 l/s)			

FIGURE 3-2

TRAIN NO. 1 BIOLOGICAL – TERTIARY P/C TREATMENT



DESIGN CRITERIA	FLOCCULATION				CHEMICAL CLARIFIER				FILTER			CARBON		
DIAMETER, FT	–				3.98[2]				0.46			0.417		
SWD[3] DEPTH, FT	–				8.83				–			–		
LIQUID DEPTH, FT	–				9.33				–			–		
SURFACE AREA, SF	–				12.41[2]				0.165			0.14		
VOLUME, GAL.	56 TO 352				1132				–			15.7		
STAGE VOLUME, GAL.	–				–				–			3.9		
TYPE	–				CONVENTIONAL				DUAL MEDIA			DOWN FLOW		
EFF. BED DEPTH, FT	–				–				2.5' A, .5' S			15		
CARBON, LBS.	–				–				–			61.7[5]		
PERCENT OF DESIGN	75	100	150	MAX.	75	100	150	MAX.	75	100	150	75	100	150
FLOW, GPM	6.6	8.9	13.4	16.0	6.5	8.7	13.1	15.7	.5	.66	1.0	.31	.42	.64
DETENTION TIME, HRS.	22[1]	16.5[1]	11[1]	8.6[1]	2.9	2.2	1.4	1.2	–	–	–	–	–	–
OVERFLOW, GPD/SF	–	–	–	–	754	1009	1520	1821	–	–	–	–	–	–
HYDRAULIC LOADING, GPM/SF	–	–	–	–	–	–	–	–	3	4	6	2.3	3.1	4.65
VELOCITY, FPM	–	–	–	–	–	–	–	–	–	–	–	–	–	–
MIXING FORCE, G, FPS/F	45	45	45	45	–	–	–	–		–	–	–	–	–
CONTACT TIME, MIN	–	–	–	–	–	–	–	–	–	–	–	50[5]	36[5]	18[6]

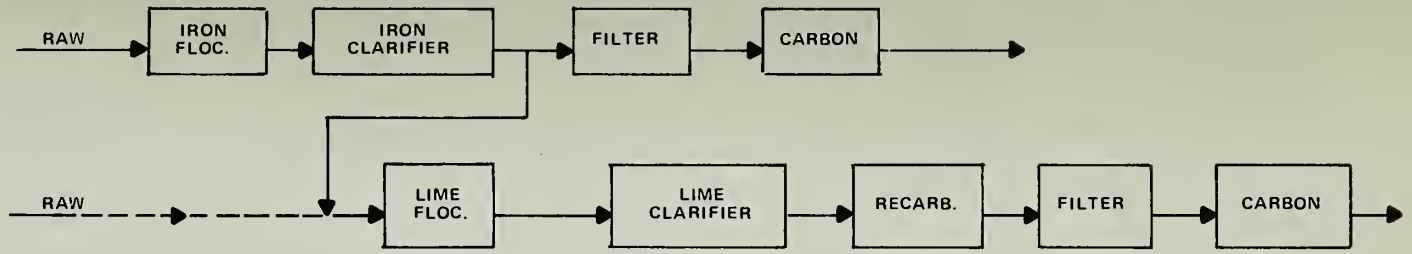
(1) MINUTES
(2) EFFECTIVE DIAMETER OR AREA (DEDUCTS AREA OCCUPIED BY CLARIFIER FEED WELL AND LAUNDER)
(3) SIDE WATER DEPTH
(4) SIDE WATER VOLUME MINUS FEED WELL
(5) 4 – 3.75' EFFECTIVE DEPTH COLUMNS
(6) 3 – 3.75' EFFECTIVE DEPTH COLUMNS

METRIC FORMULAS

FT	=	(x 0.3048 m)	GPD/SF	=	(x 0.0408 $m^3/m^2/d$)
SF	=	(x 0.0929 sq.m.)	GPM/SF	=	(x 40.7 $l/min/m^2$)
GAL	=	(x 3.785 l)	FPM	=	(x 0.3048 m/min)
LBS	=	(x 0.454 kg)	FPS/F	=	(x 1.0 m/sec/m)
GPM	=	(x 0.0631 l/s)			

FIGURE 3-3

TRAIN NO. 2 FERRIC CHLORIDE TP/C AND FERRIC CHLORIDE PP/C – LIME TP/C TREATMENT



DESIGN CRITERIA	IRON RAPID MIX				IRON FLOCCULATION				IRON CLARIFIER				LIME RAPID MIX				LIME FLOCCULATION			
DIAMETER, FT.		–				-				9[2]				-				-		
SWD[3] DEPTH, FT.		-				--				8.83				--				-		
LIQUID DEPTH, FT.						--				10.0				-				–		
SURFACE AREA, SF		-				-				63.78[2]								-		
VOLUME, GAL.		69				313 -- 1,806				5,044[4]				21.4				88.8 - 627		
STAGE VOLUME, GAL.		--				--				-				-				-		
TYPE		–				-				CONVENTIONAL				MECHANICAL MIX				MECHANICAL MIX		
EFF. BED DEPTH, FT.		--				-								–				-		
CARBON, LBS.		–				--				-				--				--		
PERCENT OF DESIGN	75	100	150	MAX.	75	100	150	MAX.	75	100	150	MAX.	75	100	150	MAX.	75	100	150	MAX.
FLOW, GPM	34	45.6	69	82.1	34	45.6	69	82.1	33	44 2	66.3	79.5	10.7	14.3	21.4	28.5	10.7	14 3	21.4	28.5
DETENTION TIME, HRS.	2.0[1]	1.5[1]	1[1]	0.8[1]	22[1]	16.5[1]	11[1]	9.2[1]	2.5	1.9	1 3	1 1	2.0[1]	1.5[1]	1 0[1]	.8	22[1]	16 5[1]	11[1]	8.3
OVERFLOW, GPD/SF	–	--	--	--	-	--	-	-	750	1000	1500	1795	-	-	-	-	-	-	-	-
HYDRAULIC LOADING, GPM/SF	–	-	-	--	-	-			-	-	-	-	-	–	–	--	--	–	-	-
VELOCITY, FPM	-	–	-	--	–	–		–	-	-						-	-		-	-
MIXING FORCE, G, FPS/F	300	300	300	300	45	45	45	45	--	-	-	-	300	300	300	300	45	45	45	45
CONTACT TIME, MIN	–	--	–	--	–	--	-	-	-	-	-	–	–	-	–	-	--	-		--

(1) MINUTES

(2) EFFECTIVE DIAMETER OR AREA (DEDUCTS AREA OCCUPIED BY CLARIFIER FEED WELL AND LAUNDER)

(3) SIDE WATER DEPTH

(4) SIDE WATER VOLUME -- MINUS FEED WELL

(5) 4 - 3.75' EFFECTIVE DEPTH COLUMNS

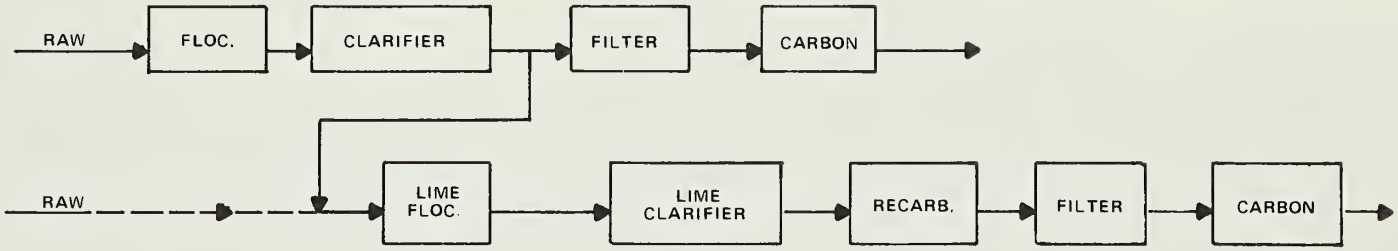
(6) 3 - 3.75' EFFECTIVE DEPTH COLUMNS

METRIC FORMULAS

FT	=	(x 0.3048 m)	GPD/SF	=	(x 0.0408 $m^3/m^2/d$)
SF	=	(x 0.0929 sq.m.)	GPM/SF	=	(x 40.7 l/min/m^2
GAL	=	(x 3.785 l)	FPM	=	(x 0.3048 m/min)
LBS	=	(x 0.454 kg)	FPS/F	=	(x 1.0 m/sec/m)
GPM	=	(x 0.0631 l/s)			

FIGURE 3-4

TRAIN NO. 2 LOW IRON – HIGH LIME P/C TREATMENT



DESIGN CRITERIA	LIME CLARIFIER	1ST STAGE RECARBONATION	RECARBONATION CLARIFIER	2ND STAGE RECARBONATION	FILTER	CARBON
DIAMETER, FT.	4.9[2]	–	2.9[2]	–	0.46	0.417
SWD[3] DEPTH, FT	8.83	–	5.08	–	–	–
LIQUID DEPTH, FT	9.50	–	5.5	–	–	–
SURFACE AREA, SF	19.0[2]	–	6.64[2]	–	0.165	0.14
VOLUME, GAL.	1647[4]	90.7	385[4]	88.5	–	15.7
STAGE VOLUME, GAL.	–	–	–	–	–	3.9
TYPE	CONVENTIONAL	CO_2 DIFFUSER	CONVENTIONAL	CO_2 DIFFUSER	DUAL MEDIA	DOWN FLOW
EFF. BED DEPTH, FT.	–	–	–	–	2.5' A. .5' S	15
CARBON, LBS.	–	–	–	–	–	61.7[5]

PERCENT OF DESIGN	75	100	150	MAX.	75	100	150	75	100	150	75	100	150	75	100	150	75	100	150
FLOW, GPM	10.2	13.6	20.4	27.2	6.0	8.1	12.1	5.9	7.9	11.8	5.9	7.9	11.8	.5	.66	1.0	.31	.42	.64
DETENTION TIME, HRS.	2.7	2	1.3	1.0	15[1]	11.2[1]	7.5[1]	1.1	0.8	0.5	15[1]	11.2[1]	7.5[1]	–	–	–	–	–	–
OVERFLOW, GPD/SF	773	1031	1546	2061	–	–	–	1280	1713	2560	–	–	–	–	–	–	–	–	–
HYDRAULIC LEADING, GPM/SF	–	–	–	–	–	–	–	–	–	–	–	–	–	3	4	6	2.3	3.1	4.65
VELOCITY, FPM	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
MIXING FORCE, G, FPS/F	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CONTACT TIME, MIN	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	50[5]	36[5]	18[6]

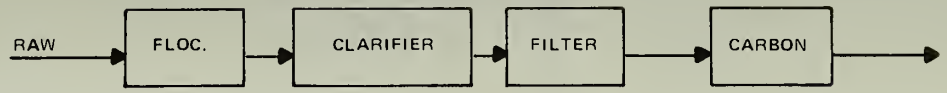
(1) MINUTES
(2) EFFECTIVE DIAMETER OR AREA (DEDUCTS AREA OCCUPIED BY CLARIFIER FEED WELL AND LAUNDER)
(3) SIDE WATER DEPTH
(4) SIDE WATER VOLUME – MINUS FEED WELL
(5) 4 – 3.75' EFFECTIVE DEPTH COLUMNS
(6) 3 – 3.75' EFFECTIVE DEPTH COLUMNS

METRIC FORMULAS

FT	= (x 0.3048 m)		GPD/SF	= (x 0.0408 $m^3/m^2/d$)	
SF	= (x 0.0929 sq.m.)		GPM/SF	= (x 40.7 $l/min/m^2$	
GAL	= (x 3.785 l)		FPM	= (x 0.3048 m/min)	
LBS	= (x 0.454 kg)		FPS/F	= (x 1.0 m/sec/m)	
GPM	= (x 0.0631 l/s)				

FIGURE 3-5

TRAIN NO. 3 ALUM TP/C TREATMENT



DESIGN CRITERIA	RAPID MIX				FLOCCULATION				CLARIFIER				FILTER			CARBON		
DIAMETER, FT.									4.66[2]				0.46			0.417		
SWD[3] DEPTH, FT									8.83									
LIQUID DEPTH, FT									9.33									
SURFACE AREA, SF									17[2]				0.165			0.14		
VOLUME, GAL.	18.3				79 - 484				769[4]							15.7		
STAGE VOLUME, GAL.																3.9		
TYPE	MECHANICAL MIX				MECHANICAL MIX				CONVENTIONAL				DUAL MEDIA			DOWN FLOW		
EFF. BED DEPTH, FT.													2.5' A; 5' S			15		
CARBON, LBS.																61.7[5]		
PERCENT OF DESIGN	75	100	150	MAX.	75	100	150	MAX.	75	100	150	MAX.	75	100	150	75	100	150
FLOW, GPM	9.2	12.2	18.3	22	9.2	12.2	18.3	22	8.9	11.8	17.7	21.3	.5	66	1.0	.31	.42	.64
DETENTION TIME, HRS.	2.0[1]	1.5[1]	1.0[1]	0.8[1]	22[1]	16.6[1]	11[1]	8.6[1]	1.4	1.1	0.7	6						
OVERFLOW, GPD/SF									750	1000	1500	1800						
HYDRAULIC LOADING, GPM/SF													3	4	6	2.3	3.1	4.65
VELOCITY, FPM																		
MIXING FORCE, G, FPS/F	300	300	300	300	45	45	45	45										
CONTACT TIME, MIN.																50[5]	36[5]	18[6]

(1) MINUTES

(2) EFFECTIVE DIAMETER OR AREA (DEDUCTS AREA OCCUPIED BY CLARIFIER FEED WELL AND LAUNDER)

(3) SIDE WATER DEPTH

(4) SIDE WATER VOLUME MINUS FEED WELL

(5) 4 - 3.75' EFFECTIVE DEPTH COLUMNS

(6) 3 - 3.75' EFFECTIVE DEPTH COLUMNS

METRIC FORMULAS

FT	= (x 0.3048 m)		GPD/SF	= (x 0.0408 $m^3/m^2/d$)	
SF	= (x 0.0929 sq.m.)		GPM/SF	= (x 40.7 l/min/m^2	
GAL	= (x 3.785 l)		FPM	= (x 0.3048 m/min)	
LBS	= (x 0.454 kg)		FPS/F	= (x 1.0 m/sec/m)	
GPM	= (x 0.0631 l/s)				

FIGURE 3-6

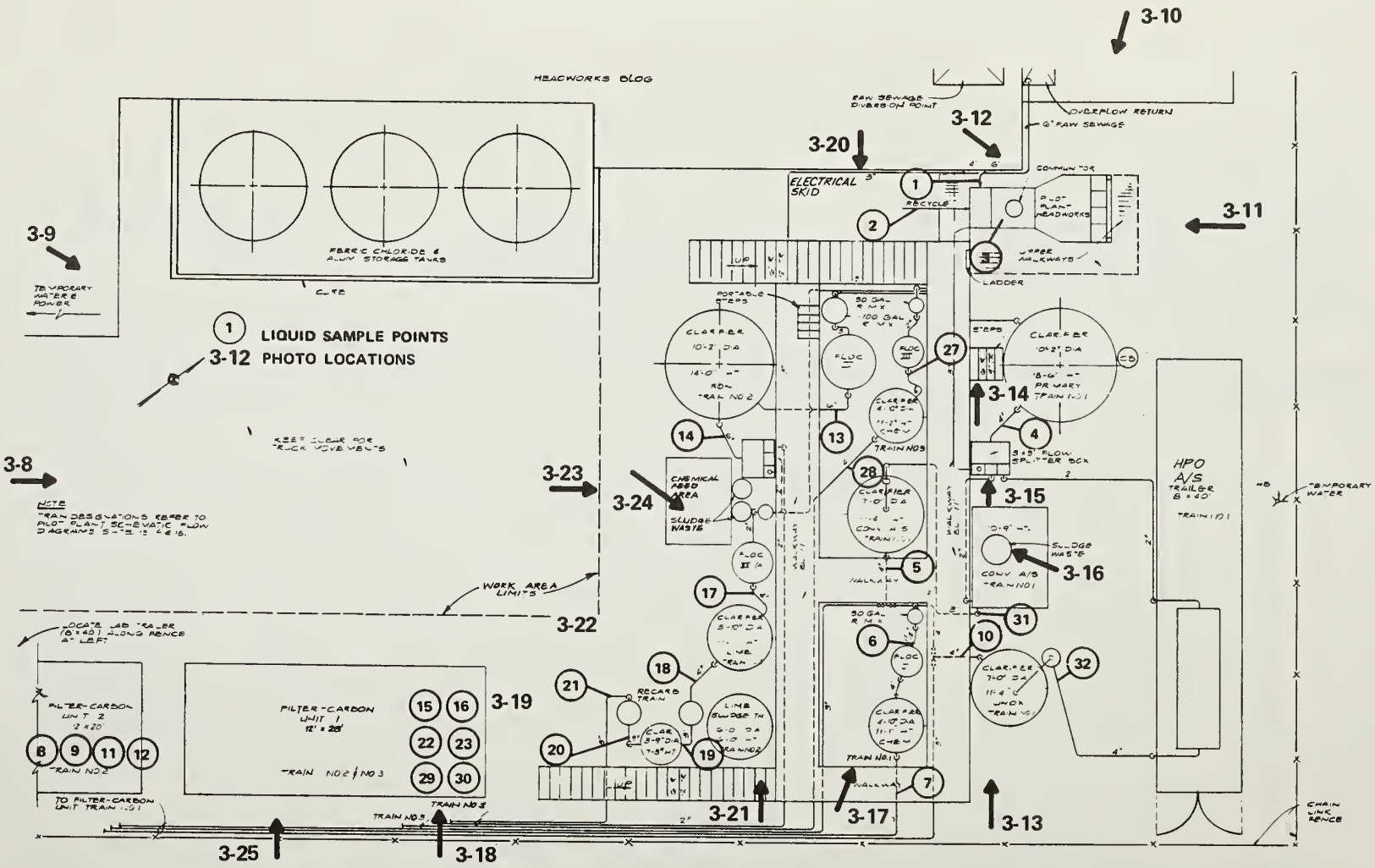


FIGURE 3-7

SAN FRANCISCO PILOT PLANT STUDY
SOUTHEAST SITE PLAN AND PHOTO LOCATIONS

portion was processed by direct filtration and carbon while the other was directed to a high lime coagulation and clarification process. The high lime effluent was passed through a two stage recarbonation process followed by filtration and activated carbon.

Train No. 3-

Train No. 3 consisted of screening and degritting with alum coagulation and clarification followed by filtration and activated carbon.

Process Selection

Process trains were selected to provide a comparison of biological and physical/chemical process removals in relation to the discharge requirements shown in Table 1-2. The process building block concept described in the introduction was used to select individual unit operations.

Train No. 1-

Train No. 1 was selected to compare the high purity oxygen and conventional activated sludge processes. Additional physical/chemical unit operations were selected to process each biological effluent to determine the point in the building blocks where discharge requirements could be met with assurance.

Train No. 2-

Train No. 2 was selected to evaluate the feasibility of using ferric chloride and lime in a two stage physical/

chemical process. The goal of this process was to remove a sufficient amount of organic solids with a ferric coagulation and clarification process so that the effluent when coagulated with lime would produce a recalcineable lime sludge. The ferric sludge would be treated separately by anaerobic digestion. An additional benefit of this process was to evaluate additional constituent removals, especially total chromium, by the lime coagulation process. Also a ferric physical/chemical process could be evaluated by direct filtration and activated carbon adsorption of the ferric clarifier effluent.

Train No. 3-

Train No. 3 provided further comparison of physical/chemical processes using alum as the primary coagulant.

Design Mobility

The pilot plant was designed to facilitate moving it to another location, such as the North Point or Richmond-Sunset water pollution control plants. Flexible polyethylene pipe with slip joints was used for process piping less than 3 inches in diameter. Larger piping was designed so the PVC could be cut and connected easily with PVC unions. Scaffolding, walkways, stairways, and platforms were bolted together in modules for ease of reconstruction. Wooden cribbing was used for construction foundations. Filter and carbon column processes and associated tankage were placed on skids.

Electrical equipment such as transformers, control panels, and motor starters were located on one centrally located skid. Electrical wiring was accomplished with heavy duty flexible conduit. Quick connect plug fittings were used for electrical connections to equipment. All fabricated tankage was equipped with ample lifting eyes to facilitate loading and placement.

Raw Sewage Pumping

Two submersible nonclog pumps were provided to pump the pilot plant raw sewage to the headworks. A discharge header designed to allow nonstop sewage pumping from the Southeast plant's two influent channels is shown in Figure 3-10. The headworks, shown in Figures 3-11 and 3-12, fulfilled three purposes: (1) to grind or comminute the raw sewage, (2) to degrit it, and (3) to meter the raw sewage flow to the appropriate process trains. A comminutor was provided for grinding with a rag trap to collect large objects in the raw sewage. An aerated grit chamber was provided for degritting the comminuted sewage.

There were three sets of weirs on the headworks. The first was a 4-inch (10.2 cm) rectangular weir located upstream from the comminutor. It was sized to proportion the necessary amount of raw sewage to operate all the pilot plant process trains. The excess raw sewage returned directly to the Southeast plant influent channel.

The second set of weirs was designed to measure the flow to each of the pilot plant trains. Four "V" notch and one rectangular weir were included in this portion of the headworks.

The third set of weirs was designed to proportion the Southeast sewage with North Point sewage. These were located in a separate box adjacent to the headworks. Also at the headworks, a flow splitter box was provided to gravity feed solids handling recycles from the main Southeast plant into the pilot plant sewage flow. A recessed vortex submersible pump was provided to pump the recycles to the flow splitter box since this material, because of its characteristics, was prone to plug centrifugal pumps and the associated pipelines.

All eight clarifiers at the pilot plant were designed with the same configuration. Each had the same collection mechanisms and steel construction. A coal tar epoxy coating was specified for the interior of the clarifiers. A skimming device was provided for all clarifiers, except the Train No. 1 physical/chemical and the recarbonation clarifiers. The skimming device consisted of a 1-inch (2.54 cm) tygon tube designed so that it was just slightly below the weir elevation to remove floating objects from the surface of the clarifier. On Figure 3-7 the relative locations of the clarifiers are shown, along with their associated unit processes.

In Figure 3-13 the primary clarifier is shown in the background adjacent to the headworks. Sludge was removed from the primary clarifier by gravity. The sludge drawoff box is shown in Figure 3-14.

The primary effluent flow splitter box shown on Figure 3-15 was designed to meter the flow to the high purity oxygen and conventional activated sludge systems.

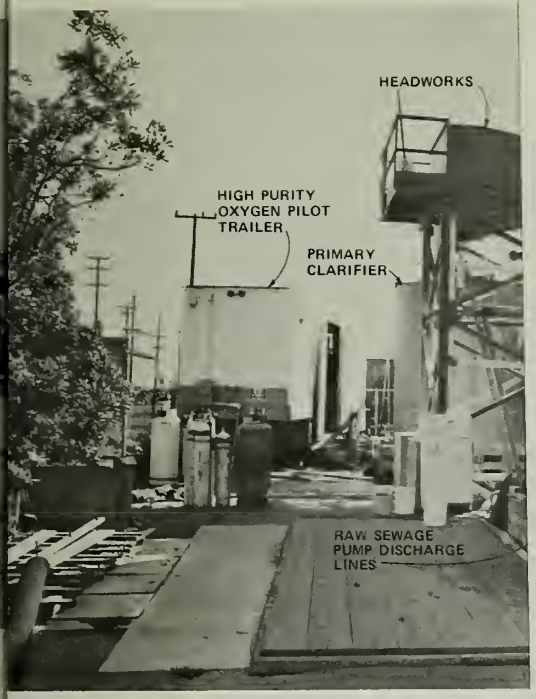


FIGURE 3-10
RAW SEWAGE PU

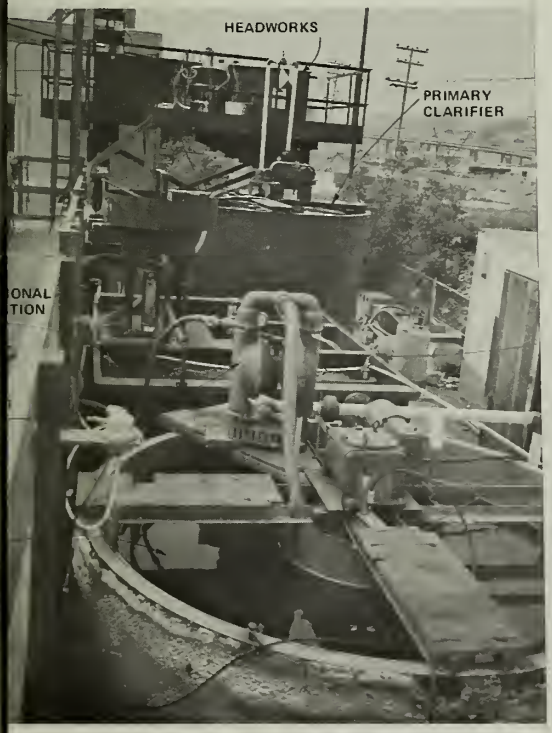


FIGURE 3-13
BIOLOGICAL UNITS

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FIGURE 3-8
SOUTHEAST PILOT PLANT

FIGURE 3-9
SOUTHEAST PILOT PLANT

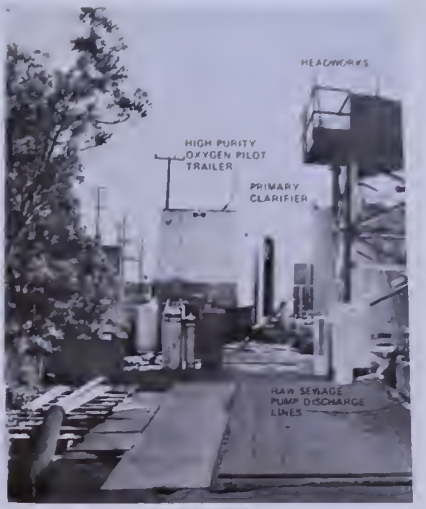

FIGURE 3-10
RAW SEWAGE PU

FIGURE 3-11
HEADWORKS

FIGURE 3-12
HEADWORKS

FIGURE 3-13
BIOLOGICAL UNITS

High Purity Oxygen Activated Sludge Process

The high purity oxygen pilot system is shown on the right of Figure 3-13, and its associated secondary clarifier is shown in the foreground. This equipment was rented for the duration of the study. Further information concerning the rental unit is included in a separate report on high purity oxygen activated sludge process found in the Appendix I.

Conventional Air Activated Sludge Process

The conventional system aeration basin is located in the center of Figure 3-13. The associated secondary clarifier was located to the left of the walkway. An approximate 7 x 9 x 10 foot (2.13 x 2.74 x 3.05 meters) deep tank was provided for the aeration basin. The basin inlet was designed to simulate complete mix conditions by combining the primary effluent and return activated sludge in a header with three discharge points. The air supply for the basin was a 7.5-hp (5.6 kW) blower. The air diffusers were 2-inch (5.08 cm) PVC pipes with 1/8-inch (0.32 cm) diameter holes drilled at an angle of 45° from the bottom of the pipe.

The mixed liquor from both the high purity oxygen and conventional systems was pumped from the respective reactors to the clarifiers. This design was necessary as a result of limitations on excavation at the treatment plant site and to keep the hydraulic flow gradient as low as possible for all process trains. Air diaphragm pumps were sized to provide the required variation in primary effluent flow. A variable speed centrifugal pump was used to lift the conventional return activated sludge to the solids recycle metering box shown in Figure 3-16. The box was located on

top of the aeration basin to provide for gravity flow to the aeration basin entrance header. Activated sludge wasting was accomplished by raising or lowering the weir in the flow metering box.

Train No. 1- Physical/Chemical Process

The Train No. 1 physical/chemical process is shown on Figure 3-17.

The chemical coagulation and clarification design included separate tanks for rapid mix, flocculation, and clarification. The rapid mix tank consisted of either a 30 or 100 gallon (114 or 379 liters) tank with the overflow or outlet placed at the proper elevation to accomplish the detention times shown on Figures 3-2 through 3-6. A 1/3 hp (0.25 kW) motor affixed to a 1/2-inch (1.27 cm) stainless steel rod with two 3-blade propellers was provided as the rapid mix device. The tanks were designed so that the base materials for pH adjustment could be added upstream of the rapid mix influent. The primary coagulant could be added in the rapid mix basin and the anionic polymer could be added in the effluent line from the basin.

The flocculation tanks were designed with variable speed direct current drives for the picket fence stirring device. The flocculation tank size and outlet were designed to provide the detention times shown on Figures 3-2 through 3-6.

A positive displacement pump was provided to lift the clarifier sludge to a sludge sampling box. The box was designed so that automatic sampling, recycling to the rapid mix basin, or wasting could be accomplished with a solenoid and timer.

Filtration-

The filter design included an acrylic tube 5.5 inches (14 cm) in diameter. The filter underdrain included a multi-metal screen with two 3-inch (7.6 cm) layers of different gradations of garnet. The filter bed consisted of 0.5 (1.27 cm) feet of sand, effective size 0.5 mm, and 2.5 feet (76 cm) of anthracite coal, effective size 1.0.

A mercury manometer was provided for headloss measurement. A water meter was provided on the backwash effluent line to measure the total amount of backwash water. The maximum backwash rate was approximately 25 gallons per minute per square foot (1018 l/min/sq m). Compressed air was provided in the backwash design to aid in cleansing the filter media of entrapped solids. Tankage was provided for backwash water storage. Pumping facilities and rotometers were provided to meter the backwash water back to the rapid mix tanks to simulate prototype plant recycle flows. The filter effluent turbidity was continuously recorded. There were five identical filter modules provided at the pilot plant. Their location is shown on Figure 3-7.

The filters and activated carbon adsorption columns are shown on Figures 3-18 and 3-19.

Activated Carbon Adsorption-

There were five sets of 4-tube carbon column units at the pilot plant. The tubes were acrylic, 5 inches (12.7 cm) in diameter with a monel screen underdrain and associated piping and pumps. Approximately 3-1/2 feet (107 cm) of carbon, 12 x 40 mesh, were placed on 6 inches (15.2 cm) of pea gravel underdrain. Pressure gauges were used to measure

the headloss across the four identical columns. Sample taps were located on the effluent of each column to monitor the dissolved organic removal across each individual column. The maximum backflow rate was about 25 to 30 gallons per minute per square foot (1018 to 1221 l/min/sq m). Tankage for backwash water was provided similar to the filters. A rotometer was used to control the flow rate through the carbon columns. A water meter was provided on the column effluent to measure the total amount of effluent processed.

Train No. 2- Two-Stage Ferric-Lime Physical/Chemical Process

The Train No. 2 process is shown on Figure 3-20. The ferric rapid mix, flocculation, and clarification units are shown in the right foreground. A view of Train No. 2 from the opposite direction is shown on Figure 3-21. The lime rapid mix and flocculation are in the middle left of Figure 3-21 with the lime clarifier in the foreground. The first stage recarbonation is in the lower left of Figure 3-21.

The Train No. 2 systems were sized according to Figures 3-2 thru 3-6. They are identical in orientation with those of Train No. 1. Sludge drawoff from the ferric clarifier in this system was designed similar to that used for the primary clarifier. A flow splitter box identical with the one on the primary effluent was provided between the two chemical coagulation systems. The sludge drawoff and sampling systems for the second-stage lime coagulation were identical with those of the Train No. 1 equipment.

A two-stage recarbonation system was designed to process the second stage coagulation system's effluent. A 55-gallon (208 l) barrel was provided for the holding tank

FIGURE 3
TRAIN N
PHYSICAL-CHEMICA

FIGURE 3
TRAINS TWO A
PHYSICAL-CHEMICA

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FIGURE 3-15
FLOW SPLITTER BOX

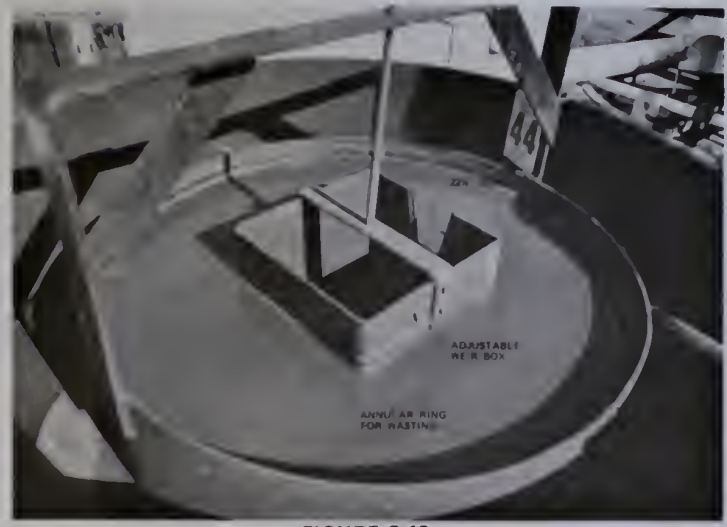


FIGURE 3-16
FLOW METERING TANK

FIGURE 3-17
TRAIN NO. 2
PHYSICAL-CHEMICAL PROCESS

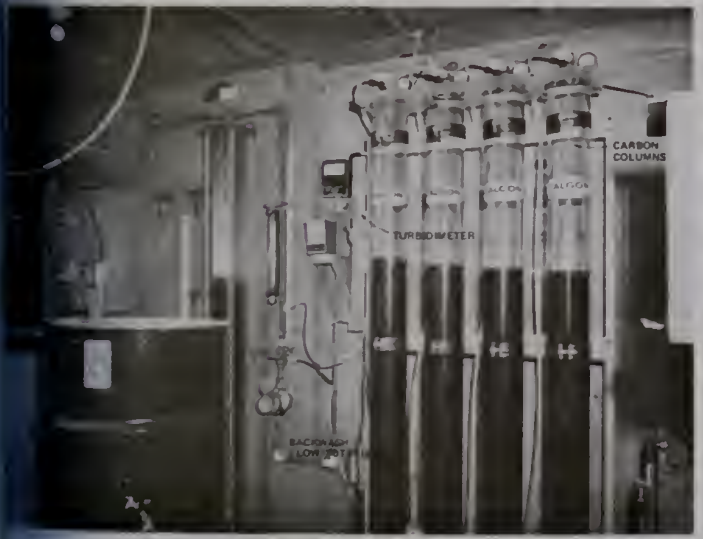


FIGURE 3-18
FILTER AND CARBON COLUMNS

FIGURE 3-19
FILTER-CARBON SKID

FIGURE 3-20
TRAINS TWO AND THREE
PHYSICAL-CHEMICAL PROCESSES

for the second stage effluent. A centrifugal pump and rotometer were sized to meter the effluent into the first stage of the recarbonation system. The reaction tank was a 55-gallon (208 l) drum provided with a plastic header for distribution of CO_2 gas from a 50-lb (22.7 kg) pressure tank. A clarifier was provided to remove the precipitated calcium carbonate solids. The design of the second stage recarbonation tank was identical with that of the first stage, both in size and in CO_2 addition. The second stage recarbonation effluent was directed to the previously described filter and carbon column modules.

The CO_2 system is shown on Figure 3-22. A gas rotometer was used to meter the CO_2 into the reaction tanks. A manifold header was provided to connect from one to four 50-pound (22.7 kg) carbon dioxide tanks to the recarbonation system.

A solids recycle box was provided to recycle lime clarifier or recarbonation sludge back to the second stage rapid mix tank to aid lime coagulation and clarification.

Train No. 3 Physical/Chemical Process

Train No. 3 is shown in the center foreground of Figure 3-20. The design of this physical/chemical train was identical with that of Train No. 1 in orientation and unit configuration. Base, primary coagulant, and anionic polymer were added at the same points as in Train No. 1. Sludge drawoff from the clarifier was similar to the Train No. 2 first stage clarifier and the primary clarifier. The effluent from this clarifier flowed to identical filtration and activated carbon modules.

Chemical Mixing

The chemical mixing area was designed so that all chemicals could be mixed at ground level to eliminate unnecessary lifting of heavy chemical bags. The mixing area is shown on Figure 3-23. Chemical feed pumps, as shown on Figure 3-24, lifted the mixed solutions to the introduction points of the respective process trains.

Sampling Equipment

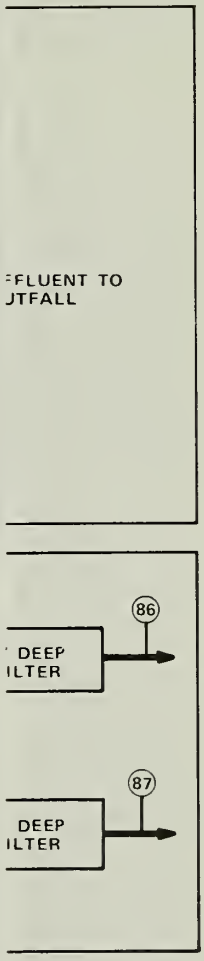
Manual collection of samples was utilized at those points where there were large amounts of solids which might cause plugging of an automatic system.

Pneumatic automatic samplers were provided to sample clarifier effluents and all downstream sampling points. A typical sampler is shown on Figure 3-25. Approximately 20 refrigerators were provided to cool the collected samples prior to pickup and analysis at the laboratory. The mobile laboratory is shown on Figure 3-26.

RICHMOND-SUNSET PILOT PLANT

As a result of property boundary constraints, existing ocean discharge, and distance from the other water pollution control plants, the Richmond-Sunset pilot plant design was modified somewhat from the original study concept. The pilot design included a combination of full-scale and pilot installations. A process flow sheet for the initial studies is shown on Figure 3-27. Full-scale facilities had been designed previously to feed sodium hydroxide for pH control, primary coagulants such as alum, ferric chloride, and cationic and anionic polymers. Since these

FIGURE
RECARBONAT



S

FIGURE 3-14
SLUDGE DRAW-OFF BOX

FIGURE 3-21
TRAIN NO. 2
LIME COAGULATION AND CLARIFICATION

FIGURE 3-22
RECARBONATION SYSTEM

FIGURE 3-23
CHEMICAL MIXING AREA

FIGURE 3-24
CHEMICAL FEEDERS

FIGURE 3-25
AUTO - SAMPLER

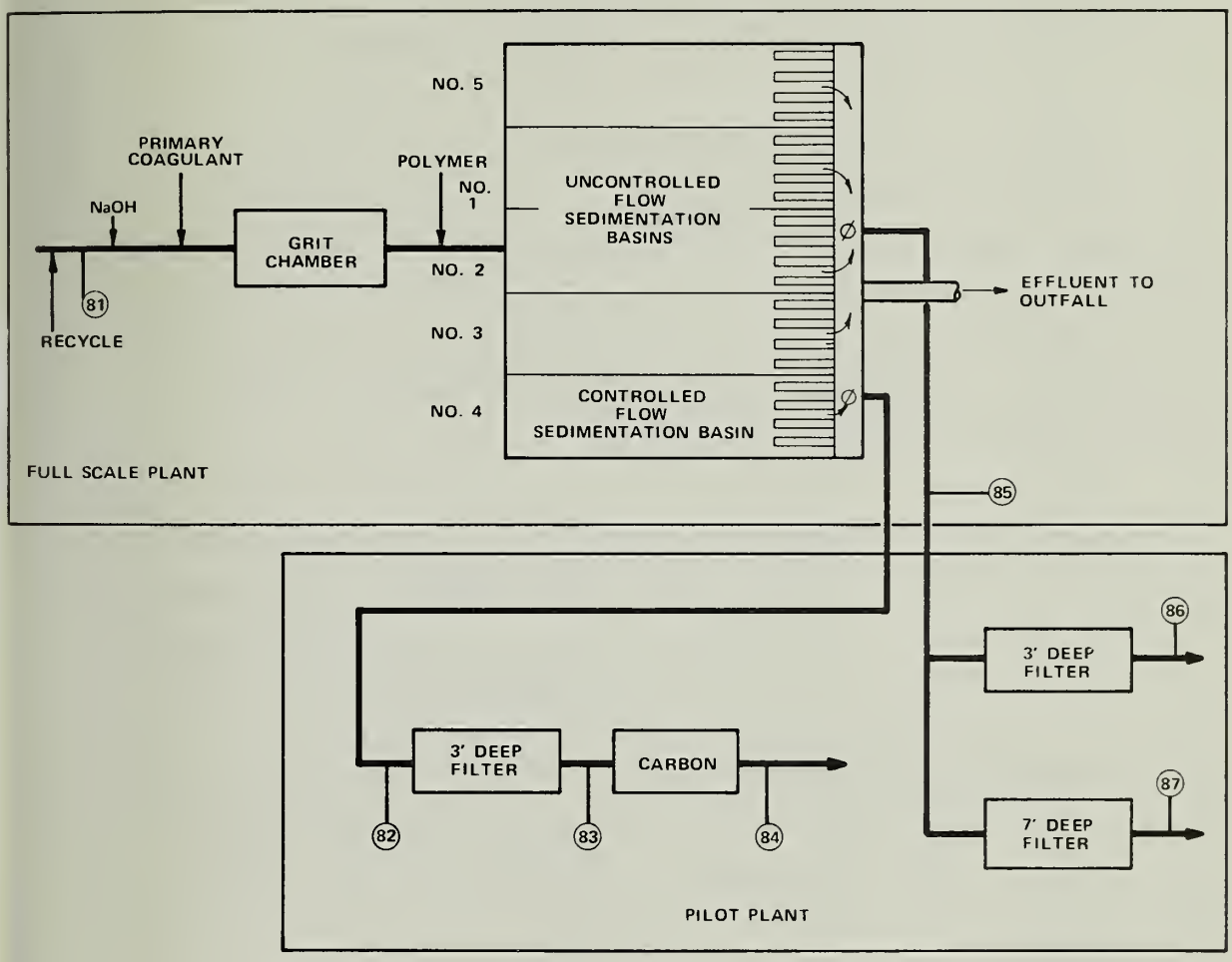


FIGURE 3-27

RICHMOND – SUNSET
PROCESS TRAINS AND DATA COLLECTION POINTS
FERRIC CHLORIDE AND ALUM TESTS

facilities were available it was decided to study full-scale coagulation and clarification. One filter-carbon column skid was moved from the Southeast site to Richmond-Sunset to study these unit processes on a pilot scale.

An automatic valve operator was provided on the influent gate valve of the No. 4 clarifier to control the basin over-flow rate. Pumping facilities were provided to convey the controlled and uncontrolled effluents to the filter-carbon column skid. The controlled effluent was processed through the 3-foot (91 cm) filter and carbon columns to study dissolved organic removals.

The second set of carbon columns (pt 87) were modified to provide a 7-foot (213 cm) dual media filter. The first two columns were used as a series filter. The first column had 3.5 feet (107 cm) of coarse anthracite, effective size 1.4 mm. The second column had 1.5 feet (46 cm) of the coarse anthracite, and 2 feet (61 cm) of sand, effective size 0.7 mm. The piping was designed to permit direct comparison of the shallow and deep filters when treating the uncontrolled clarifier effluent.

In addition, the Train No. 1 physical/chemical tankage (rapid mix, flocculation, and clarifier) was moved to Richmond-Sunset to further evaluate cationic polymers and combinations of polymers and trivalent metal coagulants. The process flow sheet is shown on Figure 3-28. Figures 3-29 thru 3-33 show the pilot installation including raw sewage pumping, surge tank, addition of chemicals to the flow metering tank, filters, and carbon columns.

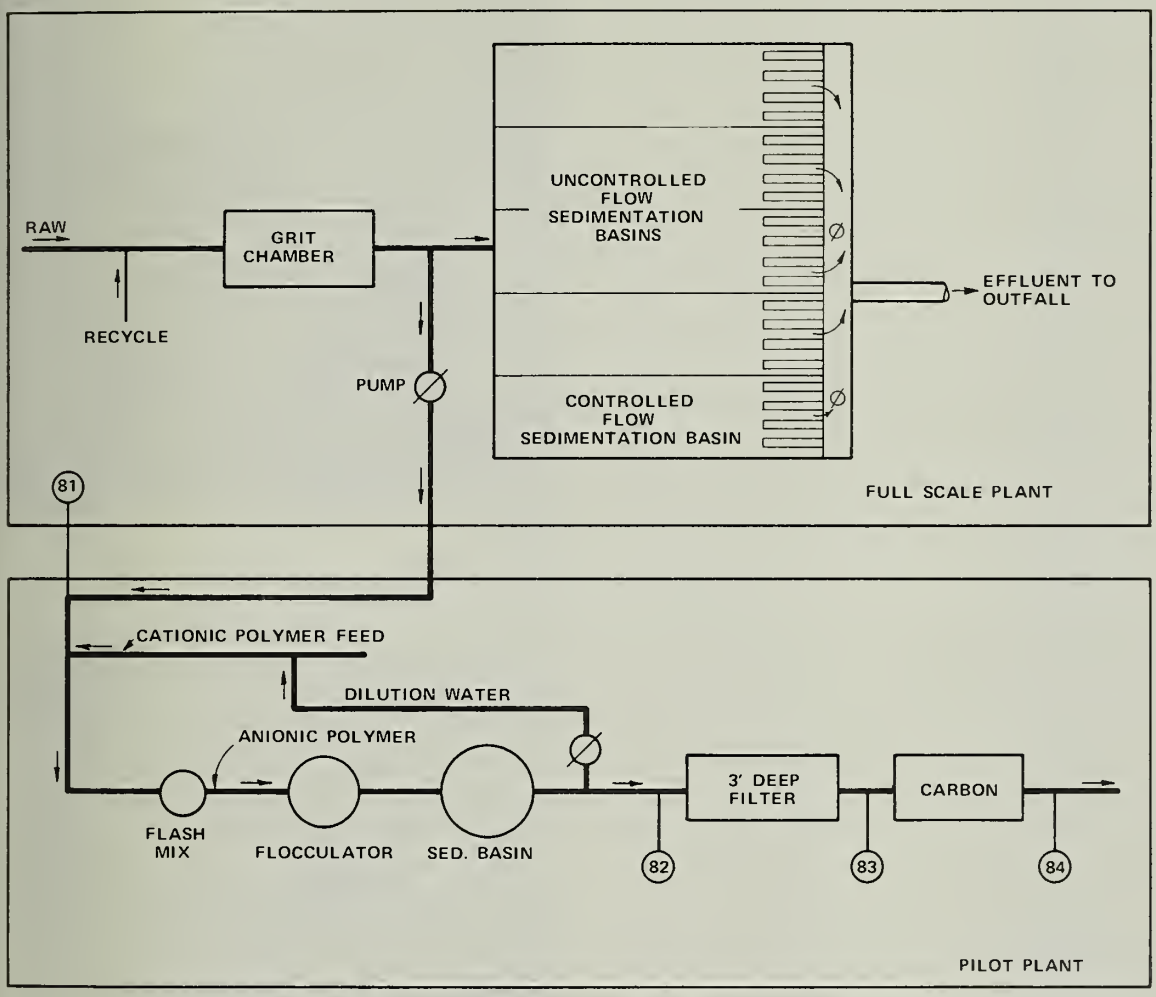
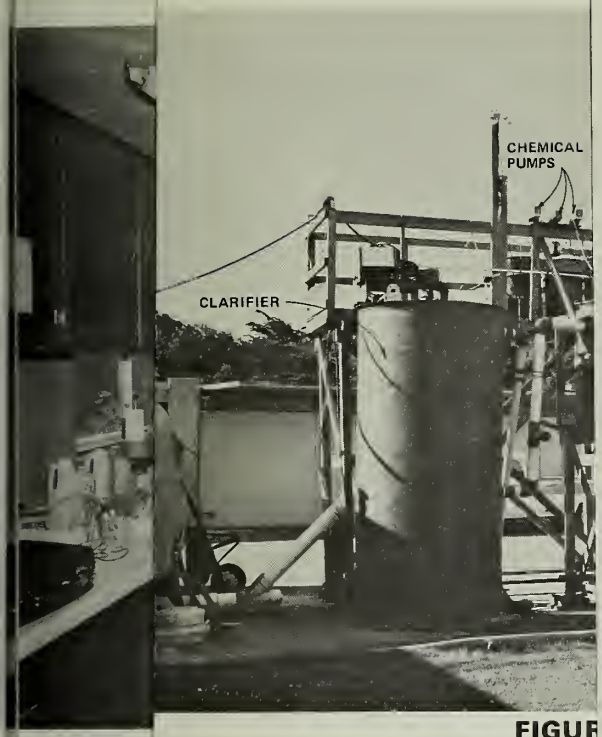


FIGURE 3-28

RICHMOND – SUNSET
PROCESS TRAINS AND DATA COLLECTION POINTS
CATIONIC POLYMER TEST



FIGUR
RICHMON
TRAIN NO. 1 - PH

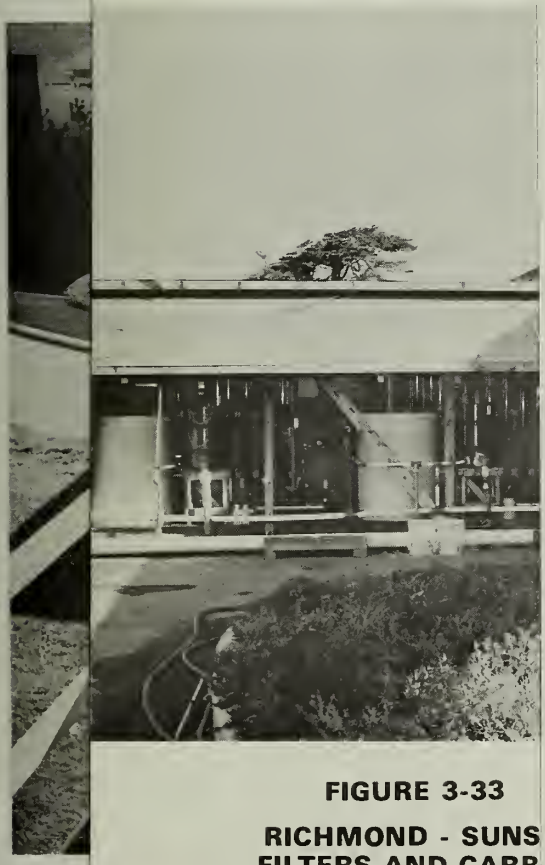


FIGURE 3-33

RICHMOND - SUNS
FILTERS AND CARB

N IV

FIGURE 3-26
MOBILE LABORATORY

FIGURE 3-29
RICHMOND - SUNSET
RAW SEWAGE PUMPING

FIGURE 3-30
RICHMOND - SUNSET
TRAIN NO. 1 - PHYSICAL-CHEMICAL

FIGURE 3-31
RICHMOND - SUNSET
PILOT INSTALLATION

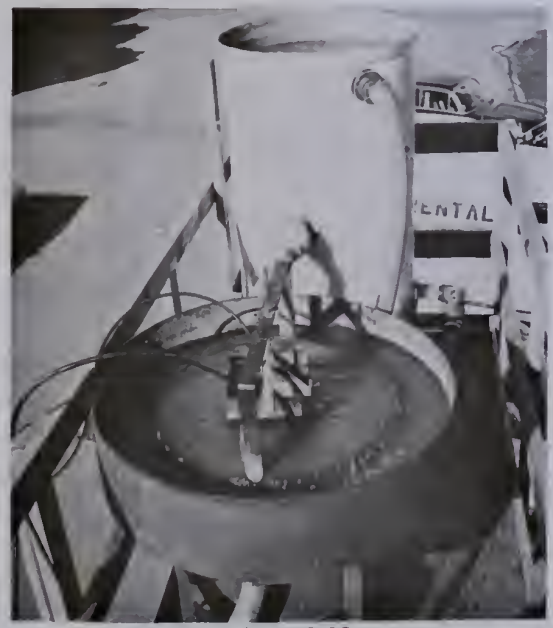


FIGURE 3-32
RICHMOND - SUNSET
SURGE AND FLOW METERING TANKS

FIGURE 3-33
RICHMOND - SUNSET
FILTERS AND CARBON

SECTION IV

SECTION IV
INFLUENT CHARACTERIZATION PROGRAM

A sampling and analysis program to characterize influent sewage was conducted at each of the three San Francisco water pollution control plants. This program was carried out to provide data which would be used to estimate the levels of constituents expected at each plant during the pilot plant operations. The sampling program involved the collection of a 24-hour, flow-proportioned composite and a peak flow grab sample on alternate days over a 2-week period. The sampling program at each plant was conducted concurrently during the weeks of April 16 and April 28, 1973. In all, 42 samples were obtained, each of which was analyzed for 108 constituents. The constituents for which analyses were performed are shown in Table 4-1.

Sample collection and field measurements were accomplished using sanitary engineering and microbiology graduate students from the University of California, Berkeley, and San Francisco State College. All sample collectors attended a 3-hour session prior to the project which reviewed the proper techniques of sample collection and onsite measurements. Project personnel worked in 8-hour shifts, beginning at midnight, during each of the seven 24-hour collection periods.

SOUTHEAST SEWAGE TREATMENT PLANT

At the Southeast plant, polyethylene buckets were used to obtain half-hourly grab samples from the influent sewer immediately ahead of the bar screens. These bucket samples were then proportioned to the proper amount and composited into a refrigerated 13-gallon (49 l) Nalgene container.

TABLE 4-1

INFLUENT CHARACTERIZATION CONSTITUENTS ANALYZED

METALS

Aluminum
Antimony
Arsenic
Barium
Beryllium
Bismuth
Boron
Cadmium
Calcium
Chromium
Cobalt
Copper
Cyanide
Iron
Lead
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Phosphorous
Potassium
Selenium
Silica
Silver
Sodium
Strontium
Thallium
Tin
Titanium
Vanadium
Zinc
Zirconium
Gold
Uranium
Lithium
Tungstun
Chrom - 6
Iron - 2

CHEMICAL

Acidity
Alkalinity
5 Day Biochemical Oxygen Demand
Ultimate Biochemical Oxygen Demand
Bromine
Carbon Dioxide
Chlorine
Chemical Oxygen Demand
Dissolved Oxygen
Flouride
Iodide
Oil and Grease
pH
Phenol
Sulfate
Sulfite
Sulfide
Surfactants
Hardness
Total Organic Carbon

NUTRIENTS

Ammonia Nitrogen
Nitrate Nitrogen
Nitrite Nitrogen
Organic Nitrogen
Total Nitrogen
Ortho Phosphate
Total Phosphate

RADIOACTIVE

Gross Alpha
Gross Beta
Radium - 226
Strontium 90

PHYSICAL

Floatables
Settleables
Total Suspended Solids
Turbidity
Color
Conductivity
Odor
Total Dissolved Solids
Total Solids
Total Volatile Solids
Volatile Suspended Solids
Temperature

BIOASSAYS

24-Hour – Median Tolerance Limit
48-Hour – Median Tolerance Limit
96-Hour – Median Tolerance Limit
24-Hour – Percent Survival Undiluted Waste
48-Hour – Percent Survival Undiluted Waste
96-Hour – Percent Survival Undiluted Waste, Toxicity Units

CHLORINATED HYDROCARBONS

Lindane
Heptachlor Epoxide
DDE
DDD
DDT
Dieldrin
Total Chlorinated Hydrocarbons
Aldrin
Chlordane
Endrin
Heptachlor
Methoxychlor
Toxaphene
Phosphated Hydrocarbons
Carbamates
2-4-D
Polychlorinated Biphenyls

Each sampler was given a schedule of sample collection and aliquot sizing. As no accurate influent metering was available, the half-hourly aliquots for the composite sample were based on flow calculations made from four existing Parshall flumes located ahead of the sedimentation basins. The flow proportioned sampling was designed to produce a sample in excess of 12 gallons (45 l) - that needed to accomplish all of the desired analyses.

During the sampling program, recycled sludge, normally introduced ahead of the Parshall flumes, was rerouted through an unused sedimentation tank. This rerouting allowed the Parshall flumes to accurately reflect the influent flow. In addition, saltwater, which was routinely added to the raw sewage to improve chemical coagulation, was eliminated during the period of sampling. These two modifications in normal plant operation allowed the sampling and analysis of a representative raw sewage sample.

In addition to the half-hourly sample collection, simultaneous measurements of dissolved oxygen, pH, and temperature were made. One chemical oxygen measurement was also made during each shift to calibrate the D.O. meter (YSI model 54). The pH meter (IL model 175) was standardized hourly by means of a standard buffer solution (pH 6.84). The sampler also recorded the plant's effluent meter approximately every 2 hours as a check on the influent flow calculations.

At the Southeast plant, as at the other plants, the daily influent flow pattern was studied for 2 weeks prior to the sampling period. On the basis of this investigation, a time was chosen each day for the collection of the peak flow grab sample. At the designated time, usually

around 1100 hours, a 12-gallon (45 l) grab sample was obtained, in a similar manner as the composite aliquots, and refrigerated.

NORTH POINT SEWAGE TREATMENT PLANT

Sample collection at the North Point plant was accomplished in a similar manner as at the Southeast plant with a few variations. Because of potential odor problems, it was not possible to shut off prechlorination of the influent, and, therefore, no uncontaminated raw sewage sample could be obtained within the plant. Sampling was therefore done at a manhole outside the plant upstream from the point of prechlorination.

At North Point accurate influent metering was available and the aliquot size could be determined directly. Onsite constituent measurements were determined at the plant using the same techniques and similar instruments as at the Southeast plant.

RICHMOND-SUNSET SEWAGE TREATMENT PLANT

At Richmond-Sunset influent samples were obtained directly behind the coarse screen and in the center channel of the 3-way flow separator leading to the grit chambers. At this plant, as at the Southeast plant, no influent flow measurement was available. To approximate the total influent flow, each of the four weirs at the end of the grit chambers was calibrated. Water height indicators were located approximately 6 feet (1.83 m) ahead of each weir to record the water depth passing from the grit chamber. These values were then averaged to obtain the resultant flow and desired aliquot size.

INFLUENT CHARACTERIZATION PROGRAM

During the sampling program at Richmond-Sunset, all sludge recycling was terminated to obtain accurate flow measurements and a noncontaminated representative influent sampling. The recycle shutoff was accomplished 1 hour before the first sample was to be taken. This early shutoff allowed the system to flush free of recycle before collection. All sample collection, onsite measurements, and data recording were accomplished in a similar manner and with similar equipment as at the North Point and Southeast sewage treatment plants.

SAMPLE HANDLING

At the end of each 24-hour collection period, the two resultant 12-gallon (45 l) samples (one composite, one grab) were transported to the North Point plant. At the North Point plant the samplers worked together to mix and distribute the collected samples to smaller containers for distribution to the laboratories for analysis. The 12-gallon (45 l) samples were split into two 5-gallon (19 l) polypropylene containers, one 1.5-gallon (5.3 l) polypropylene container, one 1-liter dark glass bottle, and one 4-ounce (118 ml) acid preserved polypropylene bottle. Each container was labeled with a preprinted NCR contact paper (3 copies) data report form. The data report forms were filled out and placed in a polyethylene envelope, attached to the respective containers, to prevent soiling or loss. The subsamples and Winkler samples were placed in refrigeration until pickup by the appropriate laboratories. All samples and aliquots were refrigerated until delivery to the various laboratories - delivery occurred within 8 hours of the final sample collection.

LABORATORY ANALYSES

The 108 constituents to be analyzed were split among four laboratories. All of these laboratories were certified by the State of California and all analyses were performed by means of Standard Methods for the Examination of Water and Wastewater, Edition 13, or by other appropriate and approved techniques. The four labs participating in the analysis program and the general analyses which they performed are as follows:

L.F.E. Environmental Laboratory: Richmond, California	Nutrients, radioactive substances, pesticides, physical constituents, oxygen analyses, and some metals.
Cook Research Laboratory: Menlo Park, California	Bioassays, halogens, miscellaneous chemical and biochemical.
Metallurgical Laboratories: San Francisco, California	Emission spectrographic, flame photometric, and some atomic adsorption metals.
F.M.C. Laboratory: San Jose, California	Total organic carbon.

In addition to the specific constituents analyzed at each laboratory, approximately 10 percent of the analyses were duplicated at one or more of the laboratories.

All analyses, except long-term measurements, were reported to CH2M HILL within 48 hours of receipt of the sample at each laboratory. At this time the 3-copy NCR data sheet was filled out with the available analyses. One copy was retained by the analytical laboratory and the other two copies were delivered to CH2M HILL and the San Francisco engineering staff, respectively. In addition to these raw data report forms, copies of all in-house calculations, standard curves, work sheets, and procedures were delivered to the City and CH2M HILL.

Within 1 week of the last analysis, a typed final copy of the constituent levels for each collected sample was delivered to CH2M HILL.

RESULTS

It has been determined that the strength of the San Francisco sewages at the time of this sampling program was less than that occurring during the dry summer months. The data should be reviewed with this fact in mind.

Data received during the Influent Characterization Program has been filed in accordance with EPA's Storet System at CH2M HILL's central computer. Apparent anomalies in the data have been identified, investigated, and corrected when errors have been found. A complete printout of the reviewed data from the Influent Characterization Program, organized by date and sewage treatment plant, and the half-hourly pH and dissolved oxygen data are presented in Appendix A.

To better examine the results of the 2-week program, the high, low and average values of each constituent have been determined for each sewage treatment plant. These calculations are presented in Appendix A. The high and low values

are determined from a review of both the composite and peak-flow grab sample data. The average constituent level, however, is calculated only from the results of the daily composite analyses. The average of composite data is believed to best represent the expected level of a constituent to be found at any given time under general climatic conditions at the time of sampling.

During the study influent pH values varied greatly. The following table depicts the range of pH values at each sewage treatment plant:

Plant	Maximum pH	Minimum pH	Range
Southeast	10.4	3.1	7.3
North Point	9.6	5.7	3.9
Richmond-Sunset	8.5	6.1	2.4

The large range and erratic fluctuations of pH at the Southeast plant suggested significant intermittent industrial contributions to the influent flow. The pH values often varied over 3 pH units between half-hour analyses. pH variations of this size, over a short time period, in approximately 20 million gallons per day (75700 cu m/day) flow can only be accounted for by industrial releases.

The North Point and Richmond-Sunset pH data reflect lower ranges and less erratic fluctuations. North Point pH data suggest some possible industrial influence, but the range of pH at North Point is approximately half of the range at Southeast.

General trends in the pH data at each sewage treatment plant show the lowest pH values to occur during late

night or early morning periods. Highest pH values normally occur during late morning or early afternoon and frequently coincide with maximum flow at each plant. At Southeast the daily fluctuations in pH are also present, but they are frequently masked by erratic pH fluctuations which appear to be the result of industrial discharges.

A review of the heavy metal data collected during the Influent Characterization Program also suggests a high correlation between industrial discharges and constituent levels analyzed at the Southeast treatment plant. The following table compares the highest concentration and constituent range for selected heavy metals normally associated with industrial processes:

	Constituent Concentration in Micrograms/liter					
	Southeast		North Point		Richmond-Sunset	
Constituent	High	Range	High	Range	High	Range
Aluminum	26,280	24,500	5,960	4,820	3,240	2,670
Cadmium	6.0	5.0	68.0	67.0	6.0	6.0
Chromium	66,000	6,553	1,100	1,082	25	21
Copper	290	170	800	670	880	804
Lead	760	710	520	490	180	148
Mercury	10.0	9.82	1.46	.98	1.52	1.28
Nickel	350	330	170	162	180	177
Zinc	4,000	3,760	450	210	450	290

Of the common heavy metals shown above, only copper and cadmium exhibited higher maximums and greater fluctuations at North Point and Richmond-Sunset treatment plants. Of all the heavy metals analyzed, most were found lower in North Point or Richmond-Sunset influent. In most cases where the highest metal data were recorded from North Point or Richmond-Sunset, the absolute level of the metal

was at or near the lower limit of detection. When the Southeast influent contained the highest metal concentrations, the levels were frequently five to ten times higher than recorded at the other plants. For example, the levels of aluminum, chromium, and zinc are significantly greater at Southeast than at North Point or Richmond-Sunset. The introduction of these metals in the observed concentrations can only be accounted for by means of industrial releases.

A significant difference in the concentration of those constituents normally found in seawater was observed between the three treatment plants. A table comparing the average concentration of the four most common constituents of seawater for each sewage treatment plant is shown below:

Constituent (mg/l)	Southeast	North Point	Richmond-Sunset	Seawater
Chloride	985	366	94	19,000
Sulfate	242	78	31	2,600
Sodium	746	372	142	10,600
Magnesium	123.9	49.6	16.5	1,300

The high concentrations of sodium, magnesium, sulfate and chloride at Southeast and North Point can only be accounted for by the infiltration or inflow of saltwater (bay water) into the sewage systems. The ratio of each constituent to each other constituent is very constant between the North Point and Southeast plants (e.g., S.E. magnesium/chloride = 0.125; N.P. magnesium/chloride = 0.133). These ratios, however, do not correlate well to similar ratios found in seawater (e.g., magnesium/chloride = 0.067). The difference in constituent ratios between the plants

and seawater is explained by 1) additions of one or more of these constituents to the sewerage system from non-seawater sources and 2) infiltration from San Francisco Bay water which does not have the same ratio of constituents as found in pure seawater (ocean water).

As observed from the above table, the concentration of seawater constituents is approximately 2 to 3 times higher in the Southeast influent than at North Point. However, as the total flow at North Point is approximately three times that of Southeast, it is estimated that the North Point system receives approximately twice the total amount of infiltration as Southeast. If Richmond-Sunset waste is assumed to be representative of domestic waste that has not been infiltrated with saltwater, it can be calculated that Southeast average daily influent contains between 1.5 and 2.6 mgd (5678 and 9841 cu m/day) of San Francisco Bay water and North Point receives between 1.3 and 2.4 mgd (4921 and 9084 cu m/day) bay water (assumes average bay water equal to two-thirds normal seawater salinity).

SECTION V

SECTION V
BENCH SCALE TESTING

Bench scale testing had several goals. The most important was the development of operating criteria for the various flow streams selected for pilot testing. The optimum range of coagulant, coagulant aids, and other chemical dosages had to be established by experimentation prior to the start of the individual data collection periods. In addition, the removal of key constituents through the simulated process trains was of utmost concern in selecting sample points for extensive collection of statistical data. It was important that pilot plant operating personnel become familiar with the range of anticipated performances for the various process trains so that the bench scale results could be used to monitor pilot plant operation. Experience from bench scale testing was used to confirm that the proper coagulant dosage range was being maintained in relation to coagulation process control, turbidity, and pH ranges.

The bench scale tests also provided information on the types and quantities of sludges that result from the addition of coagulants. Filter leaf testing gave an approximate indication of the thickening and dewaterability of some of the sludges.

In an effort to determine the daily variations in coagulation requirements for dry weather sewage, bi-hourly jar tests were run for 24 hours on the Southeast and Richmond-Sunset raw sewages. Also, tests were made to determine the effect of wet weather flow on coagulant dosages by diluting dry weather sewages with tapwater before jar testing.

The effects of abnormally high quantities of magnesium in the wastewater resulting from saltwater infiltration were evaluated in terms of applying high (pH 11.0) and low (pH 10.2) lime dosages and observing the magnesium hydroxide precipitation. Lime sludge samples were recalcined to observe the effects of the high magnesium content and the presence of high concentrations of heavy metals such as iron and chromium.

The Train No. 2 ferric chloride and lime series chemical coagulation and clarification process was evaluated in terms of the optimum ferric chloride dosage to produce an effluent, which, when coagulated with lime, would have the best recalcination value.

Two bench scale activated sludge units were operated with Southeast plant effluent as the feed source. The primary goal in this portion of the study was to learn whether or not there were toxic substances in the Southeast waste that might cause inhibition of optimum levels of activated sludge microorganisms. Another important goal was the development of operational ranges for organic loading and sludge stability for the actual pilot plant operation.

Prior to initiation of the bench scale studies, program outlines were developed using a decision-tree approach with various anticipated results and alternatives. The outlines with supporting narrative are found in Appendix B. The data summary referred to in the outline is described in Section II. It is a collection of data from other research projects across the country that employed treatment processes similar to those that might be used in the San Francisco Pilot Plant.

BENCH SCALE TESTING

BENCH SCALE PROCEDURES

The bench scale operations were conducted at the pilot plant mobile laboratory at the Southeast plant. Raw sewage samples for experimentation were collected at peak flow at each of the plants and transported to the mobile laboratory. Normally, if saltwater was being added intentionally to the sewage as a coagulant aid, it was shut off duirng sample collection; however a few tests were run with the saltwater pumps on. At the mobile laboratory the samples were mixed, proportioned, and the simulated process treatment schemes conducted as described in Appendix B.

Two gang mixers were used for the jar testing. One liter, 2-liter, and 5-gallon (19 l) samples were coagulated and clarified with the mixers. Five-gallon (19 l) samples were necessary so that sufficient treated wastewater was available for analysis for downstream processes. Parallel testing with different sample sizes indicated that there was little significant difference in solids removal among the three. The 5-gallon (19 l) samples were coagulated by locating the container under two stirrers on the gang mixer.

The jar test procedure mixing rates and times were 100 rpm and 2 minutes for rapid mix, 35 rpm and 5 minutes for flocculation, and 5 rpm and 30 minutes for dynamic settling. The base, either lime or sodium hydroxide, was added first; then the primary coagulant; then after approximately 1.5 minutes the anionic polymer was added and the mixer speed was reduced to 35 rpm for flocculation. After clarification the supernatant was decanted and the supernatant analyzed.

BENCH SCALE TESTING

Recarbonation of the lime-coagulated samples was accomplished with bottled carbon dioxide gas. Sufficient gas was bubbled through the liquid in a beaker to accomplish the two stage process. The pH was lowered to 9.5 and the sample allowed to clarify for 30 minutes. The clear supernatant was decanted and reduced to pH 7.0 to 7.5.

Filtration was simulated by filtering the processed supernatant through either a Whatman No. 2 or 3 filter paper in a Buckner funnel.

The filtrate was contacted with a 1000 mg/l dosage of powdered activated carbon for 1 hour to determine the amount of refractory dissolved organic materials present. The approximate carbon dosage was weighed and mixed with the filtrate on the gang mixer at 100 rpm. The sample was filtered with the Whatman No. 2 filter paper and analyzed.

Plexiglas activated sludge units were used for the bench scale studies. The units have a 5.7-liter aeration basin and 0.95-liter clarification section. Diffused air was used for aeration. The return activated sludge flow was by gravity.

The units were operated at a 4.5-hour aeration time and approximately 400 gpd/sq ft (16.32 cu m/day/sq m) clarifier overflow rate. Southeast plant primary effluent mixed with plant solids recycles were fed to the units at a rate of about 8 gal/day (30 l/day). A fresh batch of feed was mixed each day. Mixed liquor volatile suspended solids were maintained between 2000 and 2500 mg/l.

Lime recalcination economics were evaluated briefly with a computer program and with calcination of lime sludge samples at the mobile laboratory. The program provides information on centrifugal classification efficiencies and expected quantity and quality of the calcination furnace product. Two lime sludge samples produced during the jar testing were calcined in the lab muffle furnace at 1800° F (982° C) for 1 hour, and the product was analyzed by spectrographic analysis.

Recarbonation of the lime sludge with carbon dioxide was attempted to evaluate the possibilities of removing magnesium hydroxide. Lime sludge samples from the jar tests were placed in beakers and carbon dioxide was bubbled through the sludge layer. Magnesium was analyzed on the raw sewage, supernatant, and sludge before and after carbonation. Some limited tests were attempted to evaluate thickening and dewatering characteristics of the various sludges. Sludge samples were placed in liter graduate cylinders and agitated with a 1 to 2 rpm stirrer to simulate thickening. A filter leaf was used to simulate sludge dewatering.

Daily coagulant requirements on the Southeast and Richmond-Sunset sewages were obtained by collecting raw samples every 2 hours for 48 hours. Jar tests utilizing $FeCl_3$ and alum as the primary coagulants were conducted for the first 24-hour period and high-lime (pH 11) and low-lime (pH 10.2) for the second 24-hour period.

Additional brief studies conducted during the bench scale testing period included diluting the jar test effluents with San Francisco Bay water to observe the possibilities of post precipitation. Samples were also refrigerated to

observe the effects of temperature on post precipitation. Various dosages of chlorine were added prior to jar testing to observe possibilities of increasing coagulation efficiency. Activated silica was also evaluated briefly with lime in lieu of the anionic polymer coagulant aid. The results are discussed in Appendix B.

SECTION VI

SECTION VI
INDUSTRIAL WASTE AND SALINITY SURVEY

The industrial waste and salinity survey has pointed out the need for effective industrial waste discharge control as an essential part of any San Francisco waste treatment improvement program. It has further pointed out the problem associated with the changes in sewage density which result from changes in the amount of seawater which intrudes the sewer system.

INDUSTRIAL WASTE

The industrial waste survey consisted of continuous visual surveillance by the pilot plant operating personnel of the characteristics of the raw sewage. In addition, an intensive 1-week sampling program was undertaken in cooperation with the San Francisco Department of Public Works. Data from this sampling program are on file for review. They include half-hourly analyses for pH and chloride on samples from 13 different manholes on sewers tributary to the Southeast plant. These samples were taken during the hours between 0730 and 1730 for a period of six consecutive days starting on Monday 23 July 1973. The data identified the portions of the sewer system which were responsible for the wide fluctuations of pH and salinity experienced at the Southeast plant.

Observation of the influent sewage at the Southeast plant proved the existence of a major industrial waste control problem. Sewage colors varying from bright red to bright green were reported during the pilot plant testing. Paunch manure in various quantities periodically entered the plant.

On one occasion hot grease in sufficient quantity to completely cover the pilot plant primary clarifier with a 0.5-inch-thick (1.27 cm) layer was encountered. Animal parts continually caused problems. Animal hair and the horney part of the feet of sheep were a particular problem. Variations in pH from a low of 1.2 to a high of 11.4 were encountered. On two occasions wastes were received which had a carbonaceous BOD sufficiently high to completely exhaust the oxygen supply in the conventional air activated sludge aeration tank.

The pilot plant operators periodically noted the presence in the Southeast sewage of what appeared to be high concentration of sulfides. Under these conditions, the ferric chloride sedimentation basin would turn black. They also noted periodic discharge of material which appeared to be coconut oil. It was noted that the main plant experienced major problems in obtaining adequate chlorination as a result of the presence in the Southeast sewage of materials which caused an extremely high and varying chlorine demand. This made it extremely difficult to obtain a satisfactory reduction in coliform organisms.

A review of the constituent data obtained during the testing of the Southeast sewage indicates high concentrations of both iron and chromium. This accounts for the fact that samples of lime sludge from the bench scale tests when calcined turned green on one occasion (indicating chromium) and red on another (indicating iron). The presence of these elements was confirmed by spectrographic analysis.

The wide and rapid variations in the characteristics of the Southeast sewage made it necessary to select chemical

dosages for the operation of the pilot plant which were at times in excess of the amount actually required for satisfactory coagulation. As an example, a ferric chloride dose of 175 mg/l with 80 mg/l of lime was used throughout the tests on both the Southeast and on the blended North Point-Southeast sewages. These relatively high dosages were necessary even though bench scale tests continued to indicate that at times satisfactory coagulation could be obtained with ferric chloride dosages as low as 50 mg/l without the addition of any lime. The erratic nature of the sewage and the lack of any practical means of following the rapidly varying requirements for coagulants made it necessary to carry the higher dosages. This would also be true in the operation of a full-sized plant and emphasizes the need for research work and development of facilities for coagulant control under conditions such as those encountered at the Southeast plant.

The necessity for an intensive industrial waste discharge control program cannot be stressed too strongly. Such a program is needed both from the standpoint of treatment economy and from the standpoint of the ability of any treatment process to produce a satisfactory effluent. Such a program would have a very beneficial effect even on the quality of effluent produced by the existing primary sewage treatment facilities.

The California Water Resources Control Board and the EPA effluent requirements recognize the problem created by occasional spills of industrial wastes by permitting statistical reporting and control of effluent quality. However, the standards do not anticipate continual variations of the magnitude experienced at the Southeast plant. An effective industrial waste discharge control program

is an essential part of any plan of treatment of the Southeast sewage. This is true even if the sewage is treated in combination with that from North Point. The San Francisco Department of Public Works is implementing such a program.

Concern over heavy metals has developed only recently. Therefore permissable metal levels in industrial waste discharges into the San Francisco sewage system are not specified in the San Francisco Industrial Waste Discharge Regulations which were adopted in 1971. It would be desirable to review these regulations in the light of current limitations on metals particularly in reference to chromium.

None of the processes tested in the Pilot Plant Study was capable of producing an effluent meeting the State requirement for an effluent total chromium concentration of not more than 0.005 mg/l. All processes were able to meet other metal requirements. It is questionable whether the chromium standard can be met even with good control of industrial waste discharges. At some time it would be desirable for the regulatory agencies to review the chromium requirements to determine if it is practical to obtain the required level.

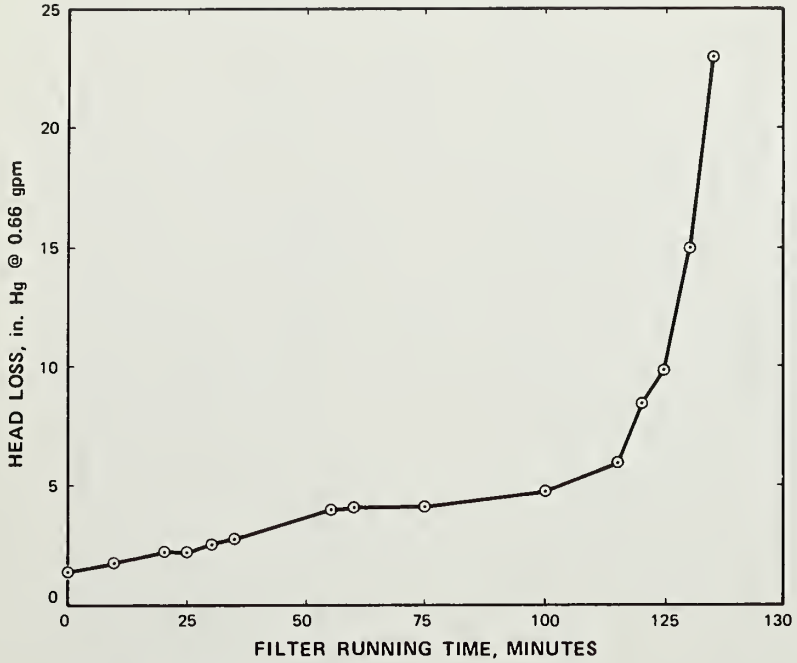
SALINITY SURVEY

One of the most significant findings of the Pilot Plant Study was a recognition of the wide variation in the salinity of both the Southeast and the North Point sewages. Tests were conducted which established the relationship between the magnesium concentration and chloride concentration and ultimately between the chloride concentration

and conductivity. Because of the ease of measurement, conductivity was then used for the ongoing monitoring of salinity.

Conductivity measurements varied from a low of 2,000 micromhos to a high of 13,500 micromhos. At any time during which the sewage salinity was dropping significantly, physical/chemical clarifiers in the pilot plant would become upset and lose sufficient flocculated solids to make filtration of the effluents impractical. It became necessary during the pilot plant testing to shut down the filters during periods of upset. If not shut down, filter runs would be reduced to less than an hour by excessive head loss buildup during these upset periods. Figures 6-1 and 6-2 show head loss curves typical of filter runs under upset clarifier conditions.

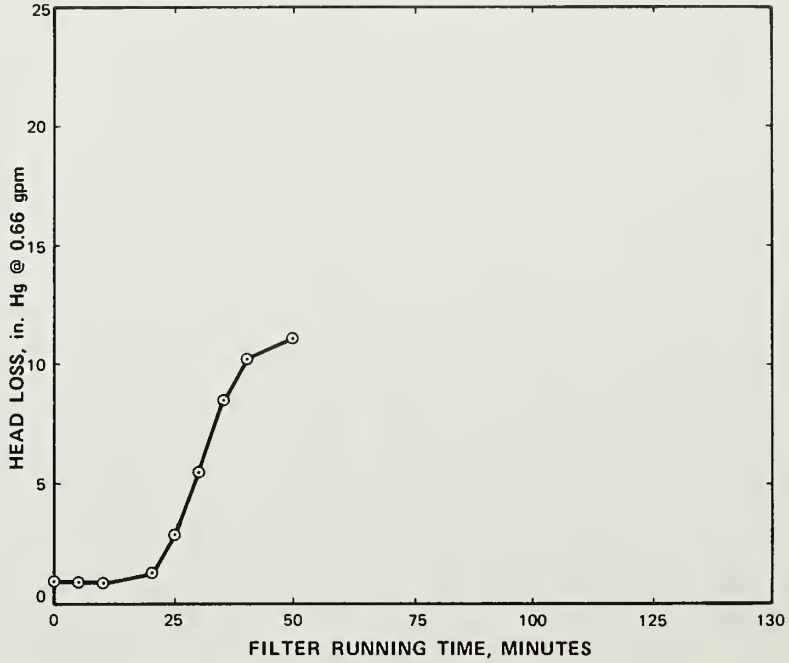
The upset problem is caused by the change in sewage density which results from the change in salinity. There is some evidence that a similar problem occurs in the full-scale plants as well as in the pilot plant. In the pilot plant, any time during which sewage density (salinity) is decreasing the lighter incoming sewage overrides the heavier sewage already in the sedimentation basin and short-circuits directly to the effluent weir. The problem was dramatically noticeable in the pilot plant basins where large quantities of well-coagulated solids were periodically observed going over the sedimentation basin effluent weirs. While the volume of these solids was sufficiently high as to preclude filtration, the weight of suspended solids lost on a daily basis was relatively low. Thus the effluent did continue to meet the suspended solids requirements of the Ocean Discharge



NOTE: Clarifier upset at time 0

FIGURE 6-1

RUNNING TIME VS. HEAD LOSS
TRAIN 2 FILTER
POINT 15
10/31/73



NOTE: Clarifier upset at time 0

FIGURE 6-2

RUNNING TIME VS. HEAD LOSS
TRAIN 3 FILTER
POINT 29
10/30/73

Policy even though it was unable to meet the EPA BOD requirements. However, any process that requires filtration downstream from a chemical clarifier requires that attention be given to the solution of the density problem before the process can be considered practical.

The first question to be answered in this regard is the source of the salinity. The relative concentrations of magnesium, sodium, and chloride during periods of high salinity indicate that the basic problem is one of seawater intrusion. In the case of the Southeast sewage, the concentrations vary generally with the tidal cycle. However, overlying the tidal cycle variations are major variations occurring on approximately a 2 to 3 hour cycle (see Figure 6-3). One can surmise that these are resulting from the discharge into the sewer system of salt water used as cooling water or wash down water by one or more industries in the Southeast area or from the periodic operation of sewage pumping stations. The variations of salinity in the North Point sewage (see Figure 6-4) which follow the tidal cycle and those in the Southeast sewage which follow the tidal cycle would appear to result either from leakage through tide gates or infiltration into the sewers. As previously mentioned, this problem is currently under study by the San Francisco Department of Public Works.

Figure 6-4 also shows the condition of the ferric chloride clarifier in relation to the conductivity of the clarifier effluent.

Abbreviations:

U - upset clarifier--settleable solids typically to 1.0 ml/l/hr flowing over the weir

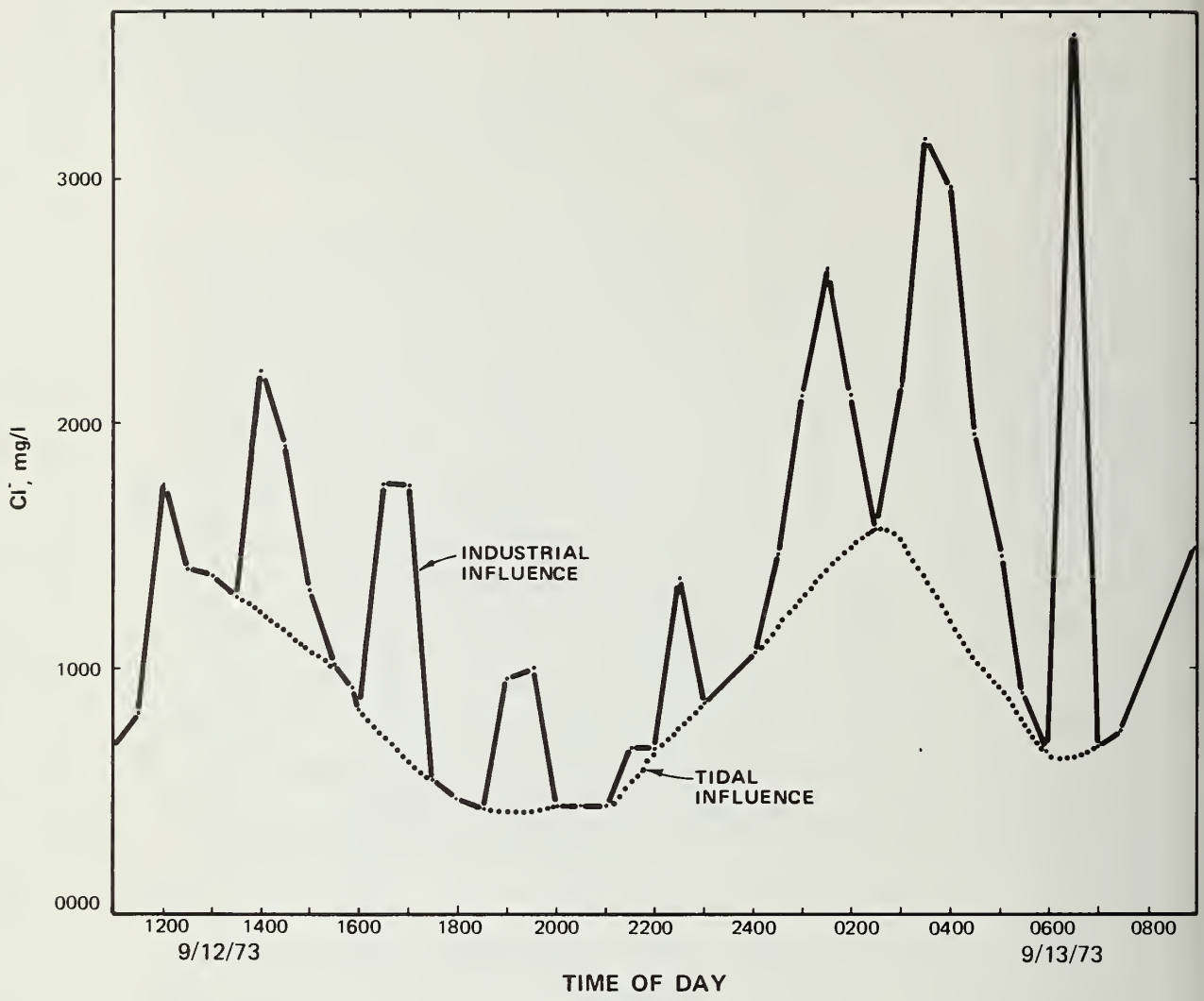


FIGURE 6-3

SOUTHEAST
CHLORIDE LEVEL RAW SEWAGE
SAMPLE POINT 1

FIGURE 6-4

NORTH POINT – SOUTHEAST
FERRIC CLARIFIER
CONDUCTIVITY AND PERFORMANCE
SAMPLE POINT 14

I - intermediate--immediately after or before the clarifier has been in an unsettled condition

S - stable condition--turbidity below 25 FTU. No settleable solids flowing over the weir.

The conductivity was measured at the effluent weir. Thus, the clarifier would become unsettled before the conductivity decreased measurably. Also, there was a significant dilution effect in the clarifier which broadened out sharp changes in salinity. In general any rapid decrease in salinity resulted in an upset clarifier. An increase in salinity stabilized the clarifier operation.

If the source(s) of the saltwater can be located and eliminated, it appears that physical/chemical treatment of the combination of North Point and the Southeast sewage can be considered. If the saltwater cannot be eliminated, other measures must be taken if the tertiary physical/chemical processes are to be considered Any procedure other than elimination will, of course, add considerably to the cost of treatment.

As an example, it would be possible to provide a holding tank ahead of the main plant and thus level out the concentration of saltwater by mixing. It is estimated that a holding basin having a capacity of as much as 10- to 20-million gallons would be required. Another possibility for control would be the addition to the incoming sewage of sufficient bay water to hold the concentration of seawater in the sewage at a reasonably constant level. Neither of these solutions appears to be practical. The Department of Public Works Infiltration and Inflow Study now in progress, will determine the source of seawater in the North Point and Southeast sewages and the practicality of its elimination.

SECTION VII

SECTION VII
PILOT PLANT OPERATION

GENERAL

This introductory section of the chapter includes a general discussion of the operational controls and problems associated with both the Southeast and North Point-Southeast testing periods.

Later discussions will be concerned with specific operational aspects of individual testing periods including the Richmond-Sunset modified operation.

The pilot plant raw sewage source at the Southeast plant was in the entrance channel immediately downstream of the plant headgates. The raw sewage is prechlorinated during dry weather periods before it enters the plant site. The raw sewage was pumped from the channel to the pilot plant headworks where the pH was monitored and recorded automatically. Temperature was measured periodically throughout the day. At the pilot plant headworks the raw sewage was comminuted, passed through a rag screen, degritted, and metered to the various process trains.

Problems encountered with the comminutor included blockage of the comb area with such items as animal hooves, tongues, and hides; plastic bottles; and metal cans. The presence of these objects required weekly removal to insure satisfactory comminution. The rag screen performed adequately although it also required frequent removal and replacement with a clean screen.

PILOT PLANT OPERATION

The aerated grit chamber performed well in degritting the sewage, however large amounts of corn and paunch manure settled out in the chamber with the grit. Such large quantities were removed that daily cleaning of the chamber was mandatory to prevent plugging of the grit drain line.

Since jar tests indicated it was desirable to add lime for pH control prior to adding the primary coagulant for physical/chemical trains, a lime slurry was added at the headworks at the weir measuring the influent to each train. The desired pH range after chemical coagulation and clarification was 6.5 to 7.5, which required an approximate dosage of 80 to 90 mg/l $Ca(OH)_2$ preceeding ferric chloride coagulation in Train No. 2 and 60 mg/l for Train No. 3. Chemical dosage was controlled by accurately measuring the flow rate of a known chemical solution. The lime slurry used was a 10 percent suspension.

TRAIN NO. 1 BIOLOGICAL FOLLOWED BY LOW ALUM PHYSICAL/CHEMICAL TREATMENT

The first unit process after the headworks in Train No. 1 was primary sedimentation. Scum and other raw sewage debris required constant skimming of the surface and grease removal from the centerwell. As a result of the large amount of grease encountered, air nozzles were added during initial operations to force the scum to the stationary skimmer more quickly. The primary sludge drawoff was operated on an intermittent basis by lowering the hydrostatic head box periodically during the day to prevent the line from plugging. Primary and all other sludge sampling was accomplished by compositing a grab sample three times a day for 7 days.

The biological process units (high purity oxygen and conventional air activated sludge processes) were operated at

identical diurnal flow rates. Average flow rate (Q) was 14 gpm (0.88 l/sec). From 0000 to 0800 hours, the systems were operated at 0.6 Q, from 0800 to 1600 hours at 1.4 Q, and from 1600 to 2400 hours at average Q. The transfer of the mixed liquor from the reactors of both units to the clarifiers with diaphragm pumps provided no noticeable problems with floc breakup or hydraulic currents in the clarifiers. However, this added one more complexity to the operation, and control of the high purity oxygen pump sump level was difficult with periodic accidental mixed liquor wasting. The high purity oxygen system operation and control is discussed more fully in a separate report found in Appendix I.

The conventional activated sludge aeration basin continually had an accumulation of greasy scum on the surface. This also appeared on the surface of the secondary clarifiers and required constant skimming. The conventional system mixed liquor dissolved oxygen concentration was maintained at 1.0 to 1.5 mg/l with constant recording of the level. The return sludge rate was maintained at 50 percent of the influent flow. Clarifier overflow rates ranged from 450 to 1000 gpd/sq ft (18 to 41 cu m/day/sq m). Testing period operational goals for the conventional system are discussed in the individual run descriptions. Food to microorganism ratios and mean cell residence time were used to control the conventional system. Wasting was accomplished on a batch basis, with the flow splitter box on top of the aeration basin.

Chemical coagulation and clarification of the conventional activated sludge effluent was accomplished with a 150 mg/l dosage of alum, approximately 50 to 60 mg/l of $Ca(OH)_2$ for pH control within a range of 6.5 to 7.5, and 0.5 mg/l

of an anionic polymer added to the rapid mix effluent. The alum solution was 20 percent and the polymer solution was 0.1 percent. It was necessary to adjust the rapid mix propeller angle to prevent a vortex forming in the basin. If the vortex was allowed to form, a continuous layer of foam formed on the flocculator surface. This situation was a potential problem for all chemical coagulation systems. The sedimentation basin overflow rate was maintained near a 1000 gpd/sq ft (41 cu m/day/sq m). The sludge drawoff for the basin was accomplished with a positive displacement pump at a rate of 0.5 gpm (0.03 l/sec). A skimmer was not necessary on this basin.

The chemically treated conventional air and high purity oxygen effluents received a chlorine dosage of approximately 3 to 5 mg/l prior to filtration to retard organic growth in the filters. Automatic pneumatic samplers were used to sample the filter influent. Filter rates were maintained at 4 gpm/sq ft (163 l/min/sq m). The backwash rate was not monitored closely, but was in the range 15 to 25 gpm/sq ft (610 to 1017 l/min/sq m). The total backwash flow was monitored and is found in the data appendix. A mercury manometer and continuous effluent turbidity analysis was used for filter control. Air addition to the final effluent backwash water assisted in proper backwashing of the filter.

The filter effluent was pumped through the carbon columns in series at a 3 gpm/sq ft (122 l/min/sq m) rate. The column backflow initiation was based on a 5 psi (0.35 kg/sq cm) differential between the first and fourth columns. The final effluent was stored and used for both filter backwash and column backflow.

TRAIN NO. 2 FERRIC COAGULATION PLUS LIME TERTIARY PHYSICAL/ CHEMICAL TREATMENT

Train No. 2 two-stage ferric-lime-physical/chemical process included the previously described lime addition at the headworks for pH control, 175 mg/l of ferric chloride added to the rapid mix basin, and 0.5 mg/l anionic polymer to the rapid mix basin effluent. A buildup of rags on the rapid mix propeller necessitated daily shaft removal and cleaning. This problem also was present in Train No. 3 rapid mix. An air skimmer similar to those on the primary and secondary clarifier was added to the Train No. 2 clarifier to remove scum more efficiently, even though the problem was not as great as on the primary. The clarifier overflow rate was maintained at 1000 gpd/sq ft (41 cu m/day/sq m). Sludge drawoff was a considerable problem with the Train No. 2 ferric chloride clarifier. Initially it was desired to return a portion of the ferric sludge to the rapid mix basin to provide a "seed" for coagulation. However, to simulate this operation, a small flow is required in proportion to the flow through the rapid mix basin. In order to achieve the low flow, two types of small pumps were tried; however the raw sewage constituents managed to plug both in relatively short periods. Finally the sludge drawoff was modified to use the hydrostatic principle as on the primary clarifier. Because the ferric sludge required continuous removal, the drawoff box level was positioned to allow a 6 to 8 gpm (0.38 to 0.50 l/sec) rate to prevent plugging. This required an increase in the total process flow rate to maintain the 1000 gpd/sq ft (41 cu m/day/sq m) overflow rate.

The problem of density changes in the wastewater as a result of saltwater addition to the system and its effect on filtration has been previously discussed in the industrial waste section. This problem resulted in an additional and vexing complexity to the plant operation.

The portion of the Train No. 2 sedimentation basin effluent directed to filtration received a chlorine dose of 5 mg/l to retard organic growths in the pipeline to the filter and in the filter. Filter operation was similar to Train No. 1. There was a considerable amount of foam on the surface of the filter influent holding tank.

The portion of the ferric basin effluent receiving high lime treatment was adjusted to pH 11.2 to 11.5 with $Ca(OH)_2$ dosages of 250 to 600 mg/l. Added to the lime rapid mix effluent was 0.5 mg/l of an anionic polymer. Scaling of the unit process lines and the rapid mix propeller was a problem, but this was anticipated. Problems were also encountered with the metering pumps in feeding the 10 percent lime suspension from a central chemical feed station. The pump suction and discharge lines plugged frequently.

A final solution was to mix the lime suspension at ground level and pump it with a relatively large centrifugal pump to intermediate continuously mixed holding tanks located adjacent to the point of lime addition. This eliminated most of the pipeline scaling and plugging problems and provided for easier servicing of the metering pumps.

A solid state pH probe with digital read out was provided in the lime flocculator to monitor the pH level. This

arrangement worked quite well, and, although the probe scaled considerably, it still performed very satisfactorily. Standardization was required every 3 days.

Since clarification was nearly always excellent due to the high magnesium content of the sewage, lime sludge was not recycled to the rapid mix basin. The clarification rate was maintained at 1000 gpd/sq ft (41 cu m/day/sq m). A skimmer was provided on this clarifier, but it was not needed.

The lime sludge was pumped to the lime sludge thickener where it was thickened from 3 percent to 4 to 5 percent. Since the sludge was about 50 percent magnesium, no further thickening could be attained. The thickened lime sludge was dewatered and recalcined with air pollution testing on a batch basis. A report describing the results is in Appendix H.

Close control of the two-stage recarbonation process was difficult to achieve with a continuous pilot operation. However, satisfactory pH ranges were maintained after the CO_2 additions, first stage pH 9 to 10, and second stage pH 7 to 8. Actual CO_2 usage was almost twice that necessary for theoretical requirements indicating the inefficient use associated with the pilot units. The clarifier overflow rate was maintained at 1700 gpd/sq ft (69 cu m/day/sq m). The additional $CaCO_3$ sludge was pumped directly to the lime thickener. The recarbonated effluent was filtered and received carbon treatment similar to that from the other Trains.

TRAIN NO. 3 ALUM TERTIARY PHYSICAL/CHEMICAL TREATMENT

Train No. 3 physical/chemical process included the previously described lime addition at the headworks for pH control, 250 mg/l of alum added to the rapid mix, and 0.5 mg/l anionic polymer to the effluent. Similar problems with rag buildup and sludge drawoff were experienced with Train No. 3 as in Train No. 2. The clarifier was provided with an air skimmer for removing the floating material in the coagulated wastewater. The clarifier was operated at 1000 gpd/sq ft (41 cu m/day/sq m) with 3 to 4 gpm (0.19 to 0.25 l/sec) continuous sludge draw off rate. The clarifier effluent was chlorinated with a 5 mg/l dosage to retard organic growths in the pipeline and in the filter. Filter and carbon column operation was similar to that in the other Trains.

Chemical mixing and additional data are shown in detail in the pilot plant operation manual, Appendix G.

SOUTHEAST PROCESS TESTING PERIOD

The start of the Southeast test period was delayed both by the density upset problems and the problems encountered with the addition of the Southeast main plant solids recycles. Because of the characteristics of the recycle material and plugging problems, plus the sewage density change problem, it was decided to discontinue addition of the recycles until the North Point-Southeast run.

From the beginning of the Train No. 1 operation in late July, extreme variations were experienced in the pH of the raw sewage. Fluctuations ranged from 1.5 to 11.4

in plant influent flows of 20 to 25 mgd (75,700 to 94,600 cu m/day). Other variations in the raw sewage quality are described in the industrial waste section. Because of concern as to the ability of the activated sludge to withstand the potential toxic effect of these variations, a procedure was set up initially to stop the flow to Train No. 1 when the pH was outside the range of 5.5 to 9.0 for more than 15 minutes. As the test proceeded it was found that the activated sludge could handle these variations and the procedure was abandoned.

The pH recorder was equipped with an alarm system for these ranges. The frequency and duration of the Train No. 1 shutdowns are shown in Table 7-1.

During the Southeast statistical data collection period, automatic samplers were used to sample all of the liquid points except the activated sludge mixed liquors, which part way through the period were switched to manual compositing. Some problems were encountered initially with the automatic samplers on the raw sewage with straining of solids as a result of rags lodged over the sampler influent. Since no recycles were added during the Southeast run, the raw sewage sample was collected after comminution; this somewhat alleviated the rag problem.

After startup in August, two brief periods of instability were experienced with the conventional air activated sludge process. In these periods, an apparent high carbonaceous waste entered the system. This depleted the dissolved oxygen in the complete mix aerator in the area of the oxygen probe. The dissolved oxygen level was near zero for 10 to 20 minutes. This resulted in a subsequent rising

TABLE 7-1

BIOLOGICAL PILOT PLANT SHUTDOWNS

DATE	TIME	pH	DURATION OF SHUTDOWN (MINUTES)	DATE	TIME	pH	DURATION OF SHUTDOWN (MINUTES)
8/2/73	1700	9.3	10	8/19/73	1100	4.0	15
8/3/73	1630	9.6	10	8/20/73	0400	10.5	15
8/4/73	0845	9.4	45	8/20/73	2300	< 4	15
8/8/73	1200	9.5	10	8/21/73	0900	3.5	25
8/10/73	1545	9.6	15		1305	2.6	30
8/10/73	2240	2.4	40		1645	3.8	15
8/15/73	0130	5.5	30	8/22/73	0530	1.2	30
8/15/73	1400	9.5	20	8/24/73	0425	3.3	20
8/16/73	0015	4.5	45		0630	9.2	–
8/16/73	1200	5.5	45	8/31/73	2200	10+	–
8/16/73	1700	5.5	60				
8/17/73	0015	5.5	60	9/10/73	0445	1.2	45
8/17/73	0600	5.5	15	9/11/73	0350	2.0	30
8/17/73	0900	9.5	45		1300	2.2	10
8/17/73	1330	> 9.0	30	9/12/73	0500	2.2	30
8/17/73	1630	3.5	30	9/14/73	2300	2.5	60
8/18/73	0230	3.0	210	9/15/73	0100	11.0	60
	0920	8.5	20		0400	2.2	120
	1140	< 3	20				

of the sludge blanket in the secondary clarifier so that a portion of the sludge was lost over the weir.

In a full-scale activated sludge plant, if a similar situation were to occur for a longer period, the loss of the active mass would not only degrade the quality of the effluent, but reduce efficiency of soluble organics removal for several days. A plant normally operating at a lower organic loading would be able to accept such loading better than a plant with a higher organic loading. Therefore, it was decided to operate the system on a conservative cell residence time of 10 days and F:M ratio of around 0.2. Based on the operating data, the actual values were 0.17 F:M and a cell residence time of 13 days. As anticipated, there was some nitrification at these loading rates. The system operated most efficiently and was most stable at a 50 percent return activated sludge rate.

The high purity oxygen process had some problems with biological coagulation for turbidity and effluent solids reduction, but in general it was much more stable than the conventional unit. The Southeast testing period is described in Phase I of the high purity oxygen report found in Appendix I.

The filter run length for the Southeast period was based on using gravity filters in a prototype plant with runs terminated at filter head loss of 7 inches (18 cm) of mercury or 5 FTU of turbidity. One exception to this was the filter following the high purity oxygen process, which was backwashed on head loss only since the filter effluent was never below 5 FTU as a result of the aforementioned biological coagulation problems. In general, most of the time the filters required backwashing because

of the head loss limitation. As a result of the wastewater density variation problems and subsequent chemical clarifier "upsets", filters 15 and 29 required backwashing almost every time an upset occurred. The decision was made on September 15 to shut off the filters and carbon columns during upset periods.

On September 10 the flow in Trains No. 2 and 3 were increased to reflect the use of the hydrostatic drawoff method and the necessity to have a continuous minimum sludge flow to avoid plugging problems.

On September 21, hydrogen sulphide odors were detected in the No. 30 carbon column effluent and sodium nitrate addition was initiated at a dosage of 20 mg/l nitrate nitrogen. The next day odors were detected in the No. 16 carbon column and the same nitrate nitrogen addition was initiated.

NORTH POINT-SOUTHEAST PROCESS TESTING PERIOD

During October approximately 5000 gallons (19,000 l) of North Point screened and degritted raw sewage were hauled each hour to the pilot plant site at the Southeast Plant. Using a specially constructed weir system, the Southeast and North Point sewages were blended at an approximate ratio of 25% and 75%, respectively.

The Southeast plant solids handling recycle flow constituted about 3 percent of the above mixture during this phase. Line plugging problems were still encountered, but recycles were added throughout the run, although at times on an interrupted basis.

During the first two days of this run, an attempt was made to sample points 33, 34, 1, and 3 with the automatic samplers. As a result of sampler plugging due to characteristics of raw Southeast sewage and the Southeast plant recycles, the samples for the above stations were composited on a manual basis by compositing a constant volume every hour.

During this testing period, the sample points around the diurnally loaded biological sample points 4, 5, and 10 were flow proportioned by changing the sample collection container after each 8 hour period and compositing the 3 samples on a flow basis after the 24-hour period was completed.

Major rain storms, each dropping about 0.75 inches (1.9 cm) of rain, occurred during the periods October 6 to 8 and 19 to 22. As a result, the strength of the blended sewage was much lower than anticipated. The decision was made to operate the conventional activated sludge system as a prototype plant might be operated upon entering the wet weather season. During the dry weather summer periods, organic loading will be higher in relation to the wet weather periods. The transition between these periods requires abnormal wasting to maintain a uniform cell residence time, constant level of biomass activity in the aeration basin, and a reasonably constant F:M ratio in the biological unit.

In a full-scale activated sludge process of 100 mgd, (378,500 cu m/day) as that contemplated for the Southeast plant, it is unlikely solids handling facilities would be able to accept the abnormal solids loadings as a result of adjusting to the lower organic loading. The operator must

anticipate this transition period and take appropriate measures or the activity of the biomass will be decreased substantially.

In an effort to evaluate the extent of this problem, the conventional system was operated at approximately the same mixed liquor volatile suspended solids as in the Southeast run. As a result of the much lower organic loading and increased cell residence time, the biomass moved into the endogenous state with increased nitrification efficiency. However, with the increased nitrification, an associated deterioration of effluent quality in terms of suspended solids was experienced at the end of the run.

This run proved conclusively the need for the operator of the full-scale plant to anticipate each wet weather season and to reduce the solids inventory accordingly to maintain a satisfactory effluent in terms of solids quality. Further studies during the extended operating period are discussed later in this section.

The modified operation did not affect the comparison of the conventional and high purity oxygen system, since removals of key constituents followed the same trends for North Point-Southeast as Southeast alone.

During the North Point-Southeast run, the filter operation was modified to simulate pressure filter operation using 14 inches (36 cm) of mercury and 5 FTU as criteria for ending filter runs. This, of course, resulted in longer filter runs and larger volumes per run.

PILOT PLANT OPERATION

The chemical clarifiers for Trains 2 and 3 continued to have density upset problems, but the intensity and length of these problems were not as great as during the Southeast run. The filters and carbon columns were shut down during the turbulent periods as in the last half of the Southeast run.

Although the activated carbon was changed in the carbon columns between the two runs, hydrogen sulphide odors appeared in the Sta 30 and 16 effluents after only 1 week of testing. Sodium nitrate was added in an approximate dosage of 20 mg/l nitrate nitrogen, which reduced the odor problems. However, the effluent appearance indicated biological activity in the columns. One possible cause might have been inadequate chlorine dosages to remove the buildup of slime growths in the line from the clarifiers to the filter influent holding tank.

PHYSICAL/CHEMICAL HIGH FLOW RATE TESTS

During the day shifts of October 30-31, 1973, tests were run on the Southeast sewage alone through the clarifiers for Trains 1 P/C (low alum), 2 (ferric), 2A (lime), 3 (high alum) at 200 percent of design flow. The duration of these tests were 4-1/2 and 5 hours for each of the 2 days respectively. Train 1 P/C flows were run on October 31 only. Train 3 flows were run on October 30 only. Tests for the clarifiers for Trains 2 and 2A were conducted on both days. The parameters monitored every 30 minutes were conductivity, pH, and turbidity of the four clarifier effluents.

The tests produced the following results (averages):

Train	Sample Point	pH	Turb (FTU)
1	7	6.5	4.6
2	14	6.8	28
2A	18	11.3	3.5
3	28	7.1	34

pH was monitored as a control on the physical/chemical processes. Effluent turbidity was used as the indicator of clarifier efficiency, as no other tests for constituents of concern were conducted during this abbreviated testing period.

The data from turbidity tests conducted on the Southeast sewage during formal testing provided the following results for comparison:

Sample Point	pH	Turbidity
7	6.9	5.2
14	6.6	20
28	6.9	22

The limited data indicate a slightly higher turbidity for the samples collected from the effluent from the clarifiers for Trains 2 and 3 (sample points 14 and 28 respectively). Turbidities were not monitored at sample point 18 during

formal Southeast testing.

Visual monitoring of the clarifiers during higher flow rates did not indicate significant detrimental effects of the higher rates on the clarifier operation, indicating that the clarifiers had not been pushed to the failure point with the 200 percent flow rate which was equivalent to a surface loading rate of 2000 gpd/sq ft (82 cu m/day/sq m). These data simply indicate the efficiency of the pilot plant clarifiers. Extrapolation to prototype design is not possible. Data from full-scale plant operation at Richmond-Sunset presented later in this section provides a basis for establishing design parameters for the clarification of chemically coagulated wastewaters.

The clarifiers for Trains 2 and 3 did "upset" during each testing period. However, this was also experienced during normal 100 percent design flow operation, indicating that "upset" conditions were caused primarily by density currents in the clarifiers and not excessive clarifier overflow rates.

PILOT PLANT OPERATION

EXTENDED CONVENTIONAL ACTIVATED SLUDGE OPERATION

From 4 December 1973 to 19 March 1974 the pilot plant conventional air activated sludge and ferric chloride primary physical/chemical processes were operated to provide an effluent for continuous bioassays studies by Environmental Quality Analysts under contract with the City and County of San Francisco. Data from this study are available in a separate report. The sewage source for these studies was from the Southeast plant influent only.

The additional bioassay work provided an excellent opportunity to further evaluate the activated sludge process at higher organic loadings with lower mean cell residence times. Also the stability of the process was evaluated during the wet weather season.

The goals of this phase were to operate the activated sludge system at a mean cell residence time of about 5 days and a biomass loading (#BOD removal/# MLVSS or g BOD removal/g MLVSS) at 0.3. Activated sludge wasting procedures were instituted to maintain the mixed liquor volatile suspended solids concentration at around 2500 mg/l. At this level or slightly below, the anticipated BOD concentration of the Southeast sewage for the winter wet weather period would produce a biomass loading close to 0.3. The necessary wasting to maintain this loading would result in a mean cell residence time of about 5 days.

During this study period the activated sludge process was not protected from the extreme fluctuations in pH as was done during some of the earlier studies at the pilot plant.

PILOT PLANT OPERATION

The pilot plant log of influent sewage appearance indicated the extreme fluctuations and industrial discharges which were experienced in the previous runs were still present.

On 18 January a tannery notified the City it was going to dump approximately 250,000 gallons of wastes into the collection system for about 18 hours. During the 18-hour period the activated sludge was operated for only 6 hours to protect the system. However, a few weeks later it was learned the tannery had continued to dump wastes for about 2 weeks in unknown quantities. Other than this incident, it is believed the Southeast sewage was similar to previous wet weather sewages.

The density changes in the raw sewage resulting from salt-water infiltration into the system were again experienced during this study period. The ferric chloride primary physical/chemical process exhibited the same periodic solids carryover as was present in the earlier runs.

From 8 March to 13 March, the aeration basin contents and secondary clarifier were operated as a closed system because of a labor strike at the Southeast Plant which shut off the plant influent.

RICHMOND-SUNSET OPERATION

Plant-Scale Operation

The plant-scale Richmond-Sunset testing program utilized the existing chemical-feed system. Sodium hydroxide was introduced into the sewage stream with tapwater for dilution water. The primary coagulant, with dilution water, was

introduced further downstream in the channel. The influent channel turbulance was relied upon for rapid mixing.

The sewage then passed through the plant bar screens for removal of rags and grit chambers for grit removal. Anionic polymer was added to the grit chamber effluent as an aid to flocculation.

The flow then entered the sedimentation basin distribution channel, where the flow separated into the five sedimentation basins. As stated in the design section, basin #4 (Figure 3-29) was used as the controlled-flow basin. The inlet gate could be opened or closed to regulate the amount of flow entering the tank. A description of the flow measuring device is in Appendix D-2.

The controlled clarifier effluent was then pumped through a 3-foot, dual-media filter at 4 gpm/sq ft (163 l/min/sq m) similar to the Southeast testing. The filters were backwashed when the headloss exceeded 14 inches (36 cm) of mercury. The carbon columns were operated hydraulically at 3 gpm/sq ft (122 l/min/sq m) and backwashed when a 5 psi (0.35 kg/sq cm) differential built up between the first and last columns. At this hydraulic rate, there was approximately a 30-minute contact time between the filter effluent and the activated carbon.

During the first alum test, the effluent from the four uncontrolled flow clarifiers was pumped to the 3-foot (91 cm) filter similar to the above and a 7-foot (213 cm) coarse dual-media filter. This was done to determine if increased filter media size and depth would improve filter efficiency.

The effluent from the uncontrolled basins contained such a high loading of suspended solids, however, that it was impossible to operate either of these filters for periods longer than 1 hour.

Pilot Plant Operation

As shown in Figure 3-30 thru 3-33, the Richmond-Sunset pilot plant consisted of the Train No. 1 physical/chemical system moved from the Southeast Pilot Plant. The rapid mix, flocculator, and sedimentation tanks were connected with the appropriate piping to take the effluent to the filters and carbon columns. The influent to the pilot plant was full-scale plant influent after the grit chamber.

Operational problems similar to those that had occurred at Southeast were encountered at Richmond-Sunset. It was again necessary to adjust the angle of the rapid-mix propeller to prevent a vortex and the subsequent foaming problems. A Tygon-tube skimming device was necessary to remove the floatables from coagulated raw wastewater. Because of the small flows required, it was impossible to remove raw sludge with a pumping system, and the hydrostatic head box had to be lowered every hour for sludge drawoff. The filters and carbon columns were operated as they were in the plant-scale testing.

CHEMICAL DOSAGE CONTROL

Considering the difficulty of adjusting the chemical feed rate to constantly changing flows and dosages at Richmond-Sunset, it was evident that a method of coagulant-dosage control was needed upstream from the sedimentation basins. If no method of control was used upstream from the basins, monitoring the quality of the basin effluent would be

the only measure for determining if the correct dosage had been used. Thus, any required dosage change would be offset by the detention time in the basins. For average flows at Richmond-Sunset, detention time in the sedimentation basins is about 2 hours. An operator monitoring the effluent turbidity would not know if the correct dosage had been added upstream until 2 hours later. If the dosage was incorrect and he adjusted the rate of chemical feed, he would need to wait an additional 2 hours to determine if the correct adjustment had been made.

To circumvent this time lag problem, a sample was taken in the channel after the primary coagulant, base chemical, and coagulant aid had been added. This sample was then centrifuged for 5 minutes and the turbidity of the centrate was measured. The centrifuge was used as a highly efficient sedimentation basin in this operation. For nonrainwater flows, an increase in the centrate turbidity would indicate that the dosage of the primary coagulant should be increased. With rainwater flows, when using alum or ferric, turbidity and alkalinity must both be monitored. Although the plant effluent turbidity was never as low as the centrate turbidity, there was a high degree of correlation between the increases and decreases of these two parameters.

SECTION VIII

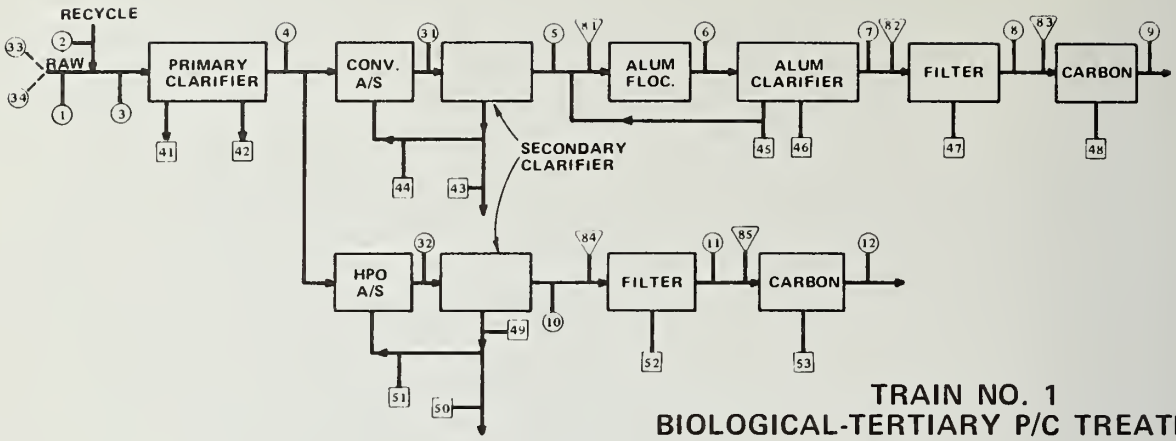
SECTION VIII
DATA COLLECTION AND PROCESSING

On Figure 8-1 are shown the data collection points in the various process trains of the North Point-Southeast pilot plant. Figure 8-2 shows the data collection points for the Richmond-Sunset plant. These figures are the keys to the data retrieval system.

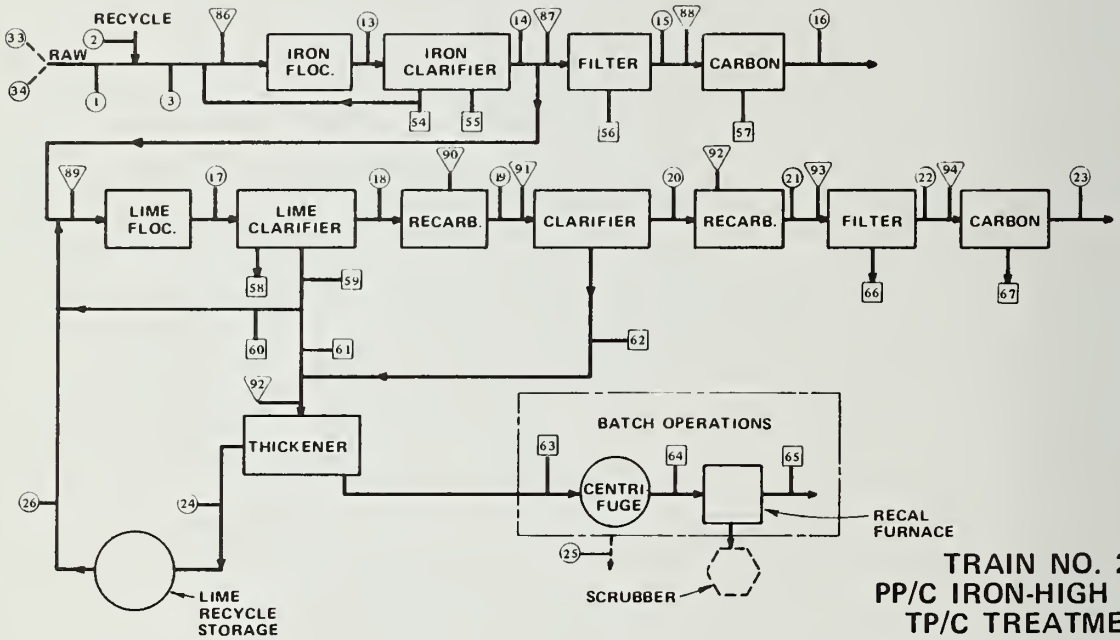
During the Southeast test, sample points 33 and 34 were not used nor was point 3. As has been previously mentioned, recycled material was not added during the Southeast test. During the North Point-Southeast test, point 33 was the Southeast raw sewage, point 34 was the North Point raw sewage, point 1 was the blended North Point-Southeast sewage, and point 3 sampled this blended sewage plus a proportionate addition of recycle from the main Southeast plant.

The liquid phase points representing potential process end points include:

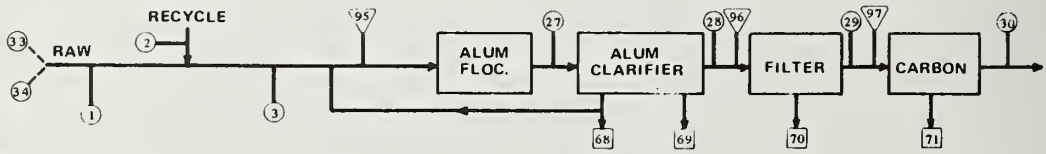
Sample Point	Process
4	Primary sedimentation
5	Conventional activated sludge
9	Conventional activated sludge plus alum coagulation, sedimentation, filtration, and carbon adsorption
10	High purity oxygen activated sludge



TRAIN NO. 1
BIOLOGICAL-TERTIARY P/C TREATMENT



TRAIN NO. 2
PP/C IRON-HIGH LIME
TP/C TREATMENT



TRAIN NO. 3
TERTIARY PHYSICAL/CHEMICAL TREATMENT

NOTES:

①	TO ㉞	LIQUID STREAM DATA POINTS
41	TO 71	SOLID OR WASTE DATA POINTS
81	TO 97	CHEMICAL ADDITION POINTS
– – – –		INDICATES NP + SE
	㉝	SE RAW
	㉞	NP RAW

FIGURE 8-1

SOUTHEAST PILOT PLANT
PROCESS TRAINS AND DATA COLLECTION POINTS

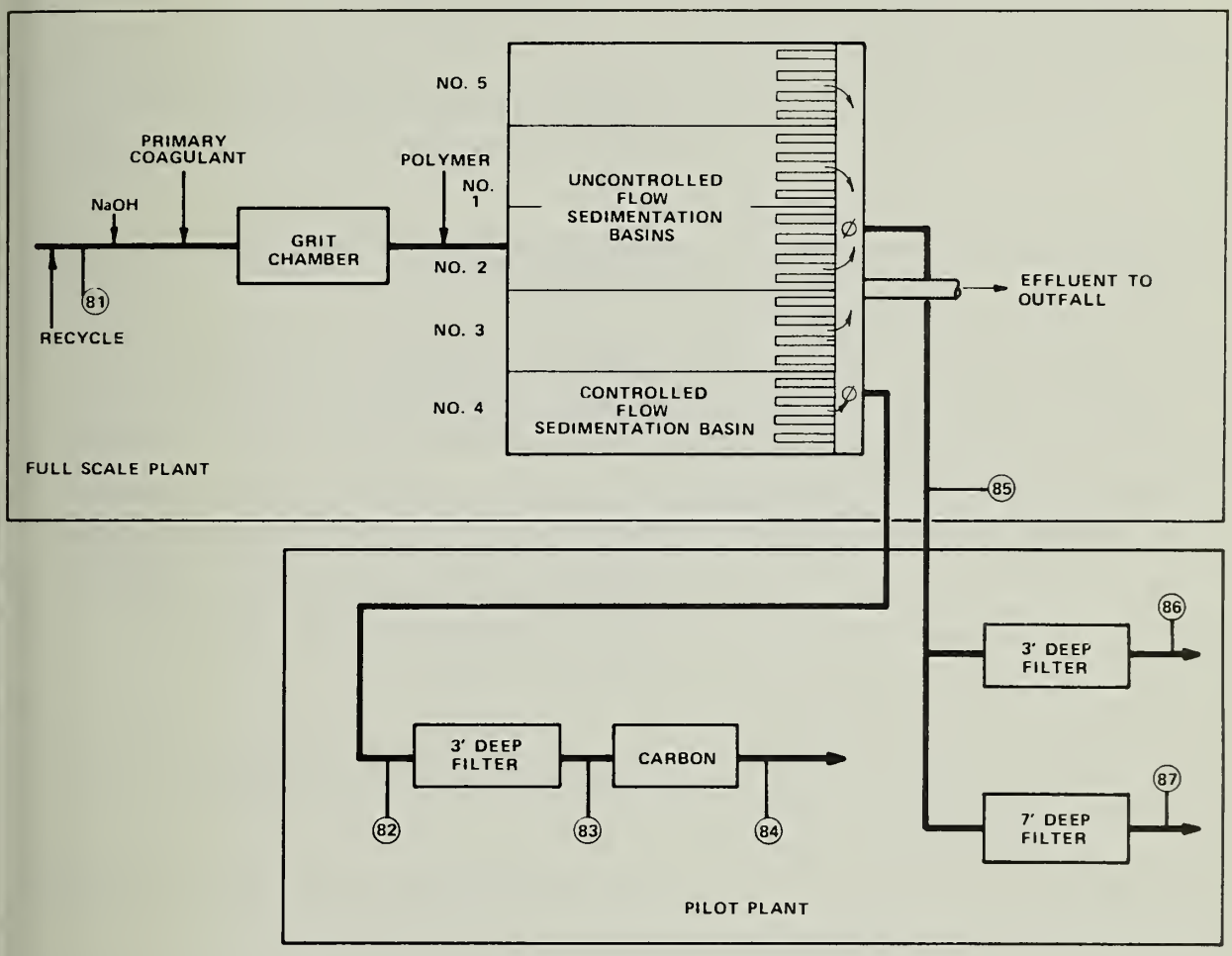


FIGURE 8-2

RICHMOND – SUNSET
PROCESS TRAINS AND DATA COLLECTION POINTS
FERRIC CHLORIDE AND ALUM TESTS

Sample Point	Process
12	High purity oxygen activated sludge plus filtration and carbon adsorption
14	Ferric chloride coagulation and sedimentation
16	Ferric chloride coagulation, sedimentation, filtration, and carbon adsorption
21	Ferric chloride coagulation and sedimentation plus lime coagulation and sedimentation plus two-stage recarbonation and sedimentation
23	The processes of 21 plus filtration and carbon adsorption
28	Alum coagulation and sedimentation
30	Alum coagulation and sedimentation plus filtration and carbon adsorption

A description of the analytical procedures used in developing process performance data is given in Appendix D. The details of sample handling, record keeping, and data processing are presented in Appendix E.

The daily data are shown in Appendixes J, K, and L.

DATA COLLECTION AND PROCESSING

The San Francisco Department of Public Works has developed a measure of process reliability based on statistical consideration of available data. An explanation of the method of computing the coefficient of reliability is shown in Appendix C.

In so far as possible, individual constituents have been coded in accordance with the EPA Storet system. The fact that the Storet system requires the recording of most constituent values in terms of micrograms per liter while most standards and most laboratory procedures record these values in milligrams per liter, creates a continuing source of potential error in the recording and interpretation of data.

SECTION IX

SECTION IX
DISCUSSION OF TEST RESULTS

It is essential when analyzing the data from the Southeast test program and the testing of the blended North Point-Southeast sewages to remember that during these tests the flow of sewage to the biological units was interrupted under conditions of high or low pH. This was done to avoid possible loss of the activated sludge and to simulate conditions which will exist when industrial waste discharges are controlled. The interruptions decreased as experience was gained in operation of the pilot plant, and they were essentially eliminated with the blending of the relatively stable North Point sewage with the Southeast sewage. In addition, it was necessary to stop the operation of the filters and carbon columns downstream from the ferric and alum chemical sedimentation basins during those periods when the basins were upset as a result of changes in sewage density. Because of these shutdowns, any conclusions which are based on the accumulated data must be prefaced with the assumption that continued enforcement of the Industrial Waste Control Ordinance coupled with the infiltration and inflow investigation will reduce these problems.

For purposes of discussing the data, the process trains will be identified by their effluent sampling points as indicated on Figures 8-1, 8-2, and 8-3.

Tables 9-1 and 9-2 are summaries of the 50 percent values from the Southeast and the North Point-Southeast test programs respectively. These values are for constituents included in one or more of the effluent requirements for discharge to the bay or ocean.

TABLE 9-1

SOUTHEAST TEST PROGRAM
CONSTITUENTS IN DISCHARGE REQUIREMENTS
PROCESS 50% VALUES

	UNITS	STAN-DARD (1)	PROCESS	CONV. A/S		H.P.O. A/S			FERRIC CHLORIDE COAGULATION				ALUM COAG.	
			RAW SEWAGE	SED. ONLY	PLUS ALUM FILT. CARB.	SED. ONLY	PLUS FILT.	PLUS FILT.& CARB.	SED. ONLY	PLUS FILT.& CARB.	PLUS LIME & RECARB	PLUS LIME FILT.& CARB.	SED. ONLY	PLUS FILT.& CARB.
SAMPLE POINT			1	5	9	10	11	12	14	16	21	23	28	30
METALS														
Arsenic	µg/l	10(2)	3.5	1.9	1	2		1	1	1	1	1	1	1
Cadmium	µg/l	20(2)	5.7	1	1	1		1	1	1	1	1	1	1
Chromium (T)	µg/l	5(2)	1,600	95	18	210		45	93	25	25	21	98	26
Copper	µg/l	200(2)	194	11	5	18		5	15	7.5	5	5	15	8
Cyanide	mg/l	0.1 (2)	0.04	0.01	0.01	0.01		0.01	0.01	0.01	0.02	0.01	0.02	0.01
Lead	µg/l	100(2)	190	17	5	19		5	8	5	5	5	10	5
Mercury	µg/l	1(2)	1.3	1	1	1		1	1	1	1	1	1	1
Nickel	µg/l	100(2)	95	46	33	53		53	62	45	19	12	45	15
Silver	µg/l	20(2)	28	1.5	1	3		1.3	2.2	1.4	1	1	2.5	1.1
Zinc	µg/l	300(2)	700	150	102	220		140	170	110	19	28	140	20
CHEMICAL														
BOD_5	mg/l	30(3)	267	11.6	3.2	10		3.2	73	29.1	44	26.3	62	23.7
BOD_5(4)	% Remove	85(3)		94	98	95		98	70	88	82	88	76	89
Oil & Grease	mg/l	5(5)	84	2.6	2	2.6		1.8	2.6	2.2	1.8	1.7	4.6	2.4
Phenol	µg/l	500(2)	300	24	1	30		1	310	1	300	1	300	1
NUTRIENTS														
Ammonia	mg/l	40(2)	14.8	8.2(6)	6.2(6)	14		14.8		14		13		13.8
PHYSICAL														
Floatables	mg/l	1(2)	6.5	2.7	0.3	2.7		0.3	1.3	0.3	1.9	0.3	1.7	0.5
Settleable Solids	ml/l	0.1(2)	9	0.1	0.1	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1
Suspended Solids	mg/l	15(5)	324	26	2.4	31	12	5.3	30	6.3	9	4.3	36.8	8.6
Turbidity (4)	FTU	10(5)	118	10	1.2	20	3	4	20	2.7	9.8	2	22	9.4
BIOASSAYS														
Toxicity	tu	1.5(2)	0.09	0	0	0		0	0	0	0	0	0	0.8
TCHC	µg/l	2(2)	1.3	0.30	0.08	0.47		0.072	0.16	0.028	0.14	0.037	0.15	0.019

(1) Most stringent standard for other standards see table 9-3.
(2) SWRCB
(3) EPA
(4) Average Values
(5) RWQCB
(6) Conv. A/S was nitrifying

TABLE 9-2

NORTH POINT – SOUTHEAST TEST PROGRAM
CONSTITUENTS IN DISCHARGE REQUIREMENTS
PROCESS 50% VALUES

	UNITS	STANDARD (1)	PROCESS	CONV. A/S		H.P.O. A/S			FERRIC CHLORIDE COAGULATION				ALUM COAG.	
			RAW SEWAGE	SED. ONLY	PLUS ALUM FILT. CARB.	SED. ONLY	PLUS FILT.	PLUS FILT.& CARB.	SED. ONLY	PLUS FILT.& CARB.	PLUS LIME & RECARB	PLUS LIME FILT.& CARB.	SED. ONLY	PLUS FILT.& CARB.
SAMPLE POINT			1	5	9	10	11	12	14	16	21	23	28	30
METALS														
Arsenic	µg/l	10(2)	2.4	2	1	1.6		2	1	1	1	1	1	1
Cadmium	µg/l	20(2)	3.1	1.2	1	1.3		1	1	1	1	1	1	1
Chromium (T)	µg/l	5(2)	435	94	33	140		40	54	40	40	32	71	40
Copper	µg/l	200(2)	150	14	89	20		5	8	40	5	8	15	10
Cyanide	mg/l	0.1(2)	0.03	0.01	0.01	0.01		0.01	0.02	0.01	0.01	0.01	0.02	0.01
Lead	µg/l	100(2)	110	18	5	22		5	7	5	5	5	10	5
Mercury	µg/l	1(2)	1.2	1	1	1		1	1	1	1	1	1	1
Nickel	µg/l	100(2)	48	32	20	40		30	41	30	19	16	27	20
Silver	µg/l	20(2)	31	3	2	3.2		1	1	2	1	1	2.4	1
Zinc	µg/l	300(2)	580	290	63	320		230	200	34	22	28	100	37
CHEMICAL														
BOD_5	mg/l	30(3)	210	7(7)	2.5(7)	6.9		3.4	33.9	14.4(7)	32	21.5	33	5.6(7)
BOD_5(4)	% Remove	85(3)		93	99	96		98	83	90	83	87	81	94
Oil & Grease	mg/l	5(5)	29.4	2	1.6	2.4		1.6	1.6	1.2	2.6	1.0	2.0	1.0
Phenol	µg/l	500(2)	170	9	2	11		1	50	1	100	1	50	1
NUTRIENTS														
Ammonia	mg/l	40(2)	14.4	0.57(6)	0.48(6)	12.4		12		13.6		12.8		13.6
PHYSICAL														
Floatables	mg/l	1(2)	0.5	0.2	0.1	0.3		0.1	0.1	0.1	0.2	0.1	0.1	0.1
Settleable Solids	ml/l	0.1(2)	3.2	0.1	0.1	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1
Suspended Solids	mg/l	15(5)	174	16	1.9	24	10	2.3	19.5	5	6.3	3.9	31	4.3
Turbidity(4)	FTU	10(5)	95	6.7	0.4	9.9	2.5	0.7	4.8	1.9	5.1	0.7	11	2.7
BIOASSAYS														
Toxicity	tu	1.5(2)	0	0	0	0		0	0	0	0	0	0	0
TCHC	µg/l	2(2)	0.5	0.06	0.016	0.04		0.018	0.04	0.011	0.05	0.012	0.07	0.007

(1) Most stringent standard for other standards see table 9-3.

(2) SWRCB

(3) EPA

(4) Average Values

(5) RWQCB

(6) Conv. A/S was nitrifying

(7) Carbon column was acting as anaerobic biological filter.

TABLE 9-3

RICHMOND-SUNSET NOVEMBER TEST PROGRAM CONSTITUENTS IN DISCHARGE REQUIREMENTS AVERAGE VALUES

	UNITS	STANDARD (1)	PROCESS	ALUM COAGULATION			
			RAW SEWAGE	SEDIMENTATION ONLY	PLUS FILTRATION	PLUS CARBON	NO. OF DATA POINTS
SAMPLE POINT			81	82	83	84	
METALS							
Arsenic	µg/l	10 (2)	3.0	1.6	1.4	1.0	5
Cadmium	µg/l	20 (2)	1.8	1.0	1.0	1.0	5
Chromium (T)	µg/l	5 (2)	29	14	12	10	5
Copper	µg/l	200 (2)	70	16	30	6	5
Cyanide	mg/l	0.1 (2)	10				3
Lead	µg/l	100 (2)	100	25	14	7.5	5
Mercury	µg/l	1 (2)	1.1	1	1	1	5
Nickel	µg/l	100 (2)	14	16	14	18	3
Silver	µg/l	20 (2)	12	4	3.4	1.3	5
Zinc	µg/l	300 (2)	200	100	130	130	3
CHEMICAL							
BOD_5	mg/l	30 (3)	141	34	23.5	9.4	11
BOD_5 (4)	% Remove	85 (3)					
Oil & Grease	mg/l	5 (5)	47.2	4.4	1.0	1.8	11
Phenol	µg/l	500 (2)	130	50	50	4	5
NUTRIENTS							
Ammonia	mg/l	40 (2)	18	13.2	12.4	11.4	11
PHYSICAL							
Floatables	mg/l	1 (2)	5.4	0.2	0.1	0.1	11
Settleable Solids	ml/l	0.1 (2)	6.0	0.3	0.1	0.1	11
Suspended Solids	mg/l	15 (5)	159	35	7.8	2.0	11
Turbidity (4)	FTU	10 (5)	70	17.2	1.9	2.8	11
BIOASSAYS							
Toxicity	tu	1.5 (2)	0.0	0.0	0.0	0.0	5
TCHC	µg/l	2 (2)	0.3	0.04	0.02	0.008	3

(1) Most stringent standard for other standards see table 9-3.
(2) SWRCB
(3) EPA
(4) Average Values
(5) RWQCB

TABLE 9-4
DISCHARGE REQUIREMENTS

CONSTITUENT		DISCHARGE REQUIREMENTS					
		OCEAN[1]		EPA[2]		BAY[3]	
		50%	10%	30-day	7-day	50%	10%
PHYSICAL							
Floatables	mg/l	1.0	2.0	NONE		NONE	
Grease and Oil	mg/l	10	15	NONE		5	
Suspended Matter	mg/l	50	75	30 85%[4]	45	15	
Settleable Matter	ml/l/hr	.1	.2	NONE		.1	
Turbidity	JTU	50	75	NONE		10	
CHEMICAL:							
BOD_5	mg/l %	NONE		30 85%	45	— 85%	—
Arsenic	mg/l	.01	.02	NONE		.01	.02
Cadmium	mg/l	.02	.03	NONE		.02	.03
Total Chromium	mg/l	.005	.01	NONE		.005	.01
Copper	mg/l	.2	.3	NONE		.2	.3
Lead	mg/l	.1	.2	NONE		.1	.2
Mercury	mg/l	.001	.002	NONE		.001	.002
Nickel	mg/l	.1	.2	NONE		.1	.2
Silver	mg/l	.02	.04	NONE		.02	.04
Zinc	mg/l	.3	.5	NONE		.3	.5
Cyanide	mg/l	.1	.2	NONE		.1	.2
Phenolic	mg/l	.5	1.0	NONE		.5	1.0
Total Cl_2 Residual	mg/l	1.0	2.0	NONE		1.0	2.0
Ammonia (N)	mg/l	40	60	NONE		40	60
TICH	mg/l	.002	.004	NONE		.002	.004
pH	—	6.0-9.0		6.0-9.0		6.5-8.5	
TOXICITY:	Various	1.5 tu	2.0 tu	NONE		40 ml/l (RT)	

1. California State Water Resources Control Board — "Water Quality Control Plan — Ocean Waters of California" July 6, 1972.
2. Environmental Protection Agency — Federal Register Vol. 3S, No. 159, Part II, "Water Programs — Secondary Treatment Information".
3. California Regional Water Quality Control Board — San Francisco Bay Regions Basin Plan — Tentative Water Quality Objectives and Waste Discharge Prohibitions—Dec. 19, 1972.
4. The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 15 percent of the arithmetic mean of the values for influent samples collected at approximately the same times during the same period (85 percent removal).

DISCUSSION OF TEST RESULTS

The constituent having the greatest impact on process selection is BOD. The following are the average BOD removal percentages obtained by the various processes. The values presented are the average of 25 daily percent removal values.

TABLE 9-5

AVERAGE % REMOVAL BOD_5

PROCESS	SAMPLE POINT	SOUTHEAST	NORTH POINT-SOUTHEAST
Air A/S	5	94	93
HPO A/S	10	95	96
Air A/S + Alum TP/C	9	98	99
HPO A/S + Carbon	12	98	98
Ferric PP/C	14	70	83
Ferric PP/C + Lime PP/C	21	82	83
Alum PP/C	28	76	81
Ferric TP/C	16	88	90
Feric PP/C + Lime TP/C	23	88	87
Alum TP/C	30	89	95

BIOLOGICAL PROCESSES

Analysis of the data for Point 5, the effluent of the conventional activated sludge process, and Point 10, the effluent of the high purity oxygen activated sludge process, support the following conclusions:

- The conventional system produces a lower effluent turbidity, a higher effluent pH, and generally provides greater removal of heavy metal.

- The high purity oxygen system provides more stable operation, better BOD and COD removal, a denser sludge, and a great buffer capacity against shock loads.

During the Southeast testing period, the primary effluent averaged 144 mg/l BOD and 186 mg/l TSS. Average effluent values for BOD and TSS, respectively were 14 and 26 mg/l. The removal rate remained very constant, as is shown on Figure 9-1, at about 90 percent. The system compared well with the High Purity Oxygen system in BOD and TSS removals. The process was fairly stable during the period with an average Sludge Volume Index of 107. The average biomass loading, lb BOD removed/day/lb MLVSS/ (g BOD removed/day/g MLVSS)averaged 0.18. At this loading the system converted about 45 percent of the ammonia-nitrogen to nitrite and nitrate.

During the North Point-Southeast testing period, the conventional system was operated in a nitrifying mode as was described in Section 7. The lower strength primary effluent and nitrification resulted in lower removal rates. From a primary effluent BOD and TSS of 110 and 122 mg/l, the conventional system effluent averaged 14 mg/l BOD and 30 mg/l

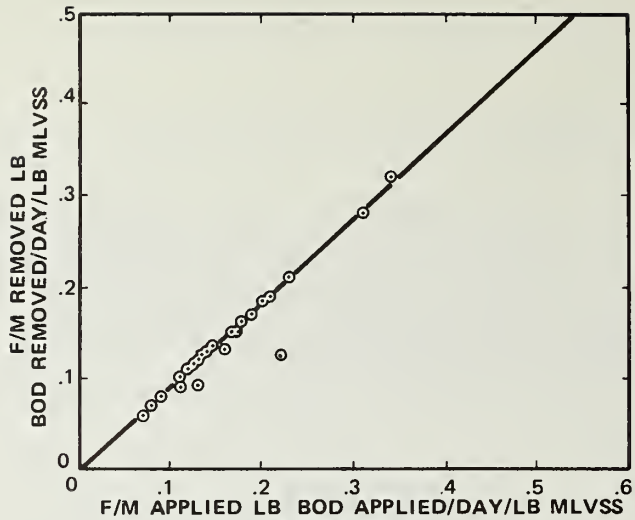


FIGURE 9-1
SOUTHEAST TEST

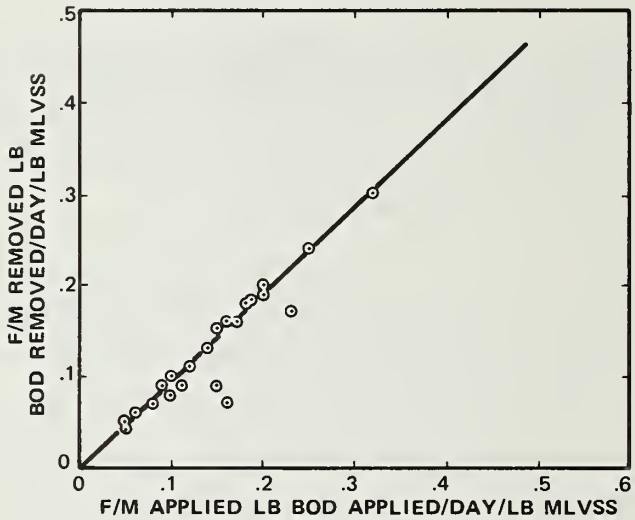


FIGURE 9-2
NORTH POINT-SOUTHEAST TEST

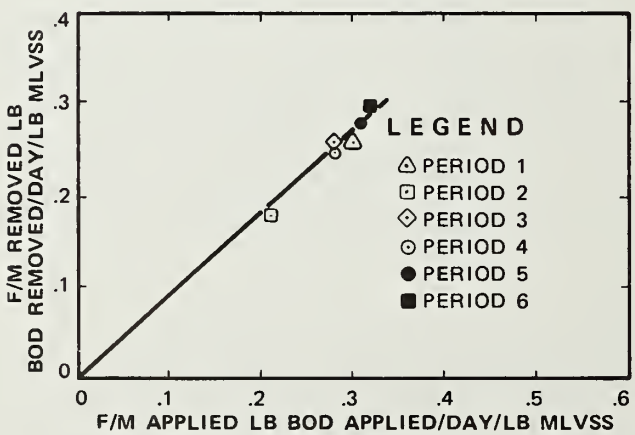


FIGURE 9-3
EXTENDED SOUTHEAST OPERATION

CONVENTIONAL ACTIVATED SLUDGE
BOD REMOVED AS A FUNCTION OF BIOMASS LOADING

TSS. The system had slightly higher values than the high purity oxygen system which averaged 7 mg/l BOD and 24 mg/l TSS. The high TSS in the conventional system effluent was a result of reduced settleability of the nitrifying organisms, with an average SVI of 120. However, the system did convert 96 percent of the ammonia-nitrogen to higher oxidized forms of nitrogen, at an average biomass loading of 0.13. The BOD removal rate, although slightly lower, remained constant during the period as is shown on Figure 9-2.

The results of the conventional system operation during the 106 day extended operating period are summarized in Table 9-6.

TABLE 9-6

CONVENTIONAL ACTIVATED SLUDGE OPERATION
4 DECEMBER 1973 TO 19 MARCH 1974 AVERAGES

Mixed Liquor, TSS	3450 mg/l	Primary Effluent, BOD	160 mg/l
VSS	2610 mg/l	Secondary Effluent, BOD	17.3 mg/l
SVI	218	Secondary Effluent, TSS	20.7 mg/l
RAS, TSS	9270 mg/l	Secondary Effluent, VSS	16.5 mg/l
RAS, VSS	6970 mg/l	Percent BOD Removal	89.5%
F/M	.25	Mean Cell Residence Time	6.4 days

DISCUSSION OF TEST RESULTS

Although the treatment efficiency was very good with effluent BOD and TSS values comparable to the earlier runs, the stability of the process was poor. The Sludge Volume Index was much higher than earlier runs. This is partially a result of a lower mixed liquor solids concentration in the SVI computation, but the significant factor in the increase was the mixed liquor settleability. At times during the period the sludge blanket level in the secondary clarifier would be very near the weir level and there were periods when a considerable amount of solids were carried over the weir.

The 106-day study was divided into 6 periods to further examine the problem of sludge stability. The resulting data are shown in Table 9-7.

TABLE 9-7

CONVENTIONAL ACTIVATED SLUDGE EXTENDED OPERATION AVERAGE VALUES

PERIOD	DATES	PRIMARY EFFLUENT BOD, mg/l	SECONDARY EFFLUENT BOD, mg/l	SECONDARY EFFLUENT TSS, mg/l	SVI	F:MA	F:MR	MCRT DAYS
I	12/4-31	169	22	–	277	.30	.26	7.3
II[1]	1/1-15	121	18	–	175	.21	.18	6.0
III	1/16-31	162	15	20	230	.28	.26	5.3
IV	2/1-15	159	17	21	147	.28	.25	4.7
V	2/16-28	177	20	23	209	.31	.28	5.5
VI[2]	3/1-19	190	13	15	240	.32	.30	10.5

(1) Wet period, low influent BOD.

(2) Labor strike, no raw sewage for 5 days.

DISCUSSION OF TEST RESULTS

In reference to the averages, the first period, during the month of December, the SVI was very high. This is probably due to the lack of attention during the month of November, when data collection was limited and the process was monitored only sufficiently to keep the microorganisms alive. The raw data indicate that almost the entire month of December was required for the system to improve in terms of sludge stability.

In the second period there was a considerable amount of rain which lowered the influent BOD and subsequent biomass loading ratios. The sludge stability improved during this period with an average SVI of 175.

During the first part of the third period, the tannery waste dump was started and the stability of the process was affected adversely. The mixed liquor settleability values increased resulting in an average SVI of 230.

DISCUSSION OF TEST RESULTS

During the fourth period the settleability improved considerably resulting in an average SVI of 147. Apparently the effects of the tannery discharge had passed through the system, resulting in the improved sludge stability.

The fifth period results indicated a sharp increase in settleability values and the average SVI. This is somewhat of a mystery since no significant industrial discharges were known during this period. Although considering the collection area and earlier experience with Southeast sewage, there could have been a significant discharge.

During the sixth period the average SVI increased again. The poor sludge stability during this period was probably a result of the labor strike with no primary effluent entering the process for 5 days.

Although the sludge stability was much poorer at the higher organic loading, the BOD and SS removal efficiency remained fairly constant. This is shown on Figure 9-3 with the BOD removed as a function of the applied biomass loading. The average BOD removal remained the same throughout the periods at 89 percent regardless of the applied loading. The average effluent SS remained fairly uniform throughout the periods, ranging from 15 to 23 mg/l.

It can be concluded that the higher organic loadings did not affect the BOD or SS removal efficiency as compared to the earlier studies. However, at the higher organic loadings the stability of the process is reduced and it is much less suited to assimilate industrial discharges without a system

upset. This was the reasoning behind using lower organic loadings during the earlier studies and a conservative approach to selected preliminary design parameters.

In general, it was noted that the operation of both of the biological units improved during periods in which storm water was in the sewer system. With the units protected from wide variations of pH and low biomass loading rates, the only indication of upset was that previously mentioned as occurring during a brief period when a short duration heavy loading of apparently high carbonaceous BOD depleted the oxygen in the conventional activated sludge aeration unit.

It should be particularly noted that if the tentative bay standard of 15 mg/l of suspended solids is to be met with assurance, filtration of the effluent from the biological units will be necessary.

The data collected at Point 9 indicate the extremely low constituent levels which are obtainable when biological treatment is followed with physical/chemical treatment. A relatively low alum dose of 150 mg/l was maintained to produce the results shown for Point 9. Additional removals could, of course, be anticipated with higher dosages.

PHYSICAL/CHEMICAL PROCESSES

As discussed previously, the tertiary physical/chemical treatment processes consist of the addition of chemical coagulants to the raw sewage, the settling of the coagulated solids in sedimentation basins (clarifiers) and the

treatment of the clarified effluent with filters and activated carbon. The filters are used to remove the residual solids from the sedimentation effluent and the activated carbon treatment is for removal of soluble organics. It is important to recognize that the processes are interrelated and the effectiveness of constituent removal of each process depends on the previous process. The filters, for example, will not operate satisfactorily unless the sedimentation basins have been operated correctly and the carbon column performance is dependent upon proper performance of the filters.

The optimum operation of the coagulation process depends upon the correct dosage of coagulant, base chemical, and coagulant aid added to the sewage and adequate mixing and flocculation time for these chemicals. The major operational parameters in the sedimentation process are overflow rate and sludge removal. The filters must be operated at a hydraulic loading that does not induce a high headloss in a short period of time and produces a satisfactory effluent turbidity. The soluble organics removed in the carbon columns depends upon the contact time between the wastewater and the activated carbon, as well as the nature of the organics.

This section of the San Francisco Pilot Plant Report will summarize the results of the pilot-scale physical/chemical processes tested at the Southeast Water Pollution Control Plant and the pilot and plant-scale physical/chemical processes tested at the Richmond-Sunset Plant.

Dosage Requirements

To the extent that the sewage tested reflects the actual sewage to be treated in the prototype, the determination of

chemical dosage should be excellent. The amount of chemical is determined primarily by the characteristics of the sewage rather than by the characteristics of the treating units.

North Point-Southeast-

With the Southeast sewage, the average dosage requirement for alum was 265 mg/l to achieve complete coagulation in the pilot plant. Approximately 75 mg/l of lime ($Ca[OH]_2$) was added for alkalinity control and 0.5 mg/l of anionic polymer coagulant aid. The required dosage for ferric chloride at this time was 180 mg/l, with 105 mg/l of lime added for alkalinity control and 0.5 mg/l of coagulant aid.

The blended North Point-Southeast sewage requirement for alum was lower than for the Southeast sewage alone. The dosage maintained during this test was 225 mg/l for alum, with 75 mg/l of lime and 0.5 mg/l of coagulant aid. The ferric chloride dosage was 175 mg/l, but an average of 120 mg/l of lime was needed for alkalinity control. The dosage of coagulant aid was held at 0.5 mg/l for the ferric process.

Richmond-Sunset-

The characteristics of the Richmond-Sunset sewage were different from those encountered in the North Point-Southeast tests and different dosages of the primary coagulants were required. Also, the alum and ferric chloride tests were conducted on a plant scale at Richmond-Sunset.

The difference in dosage requirements reflects not only the differences in the chemical characteristics of the

sewages but also the differences between the pilot and full scale plant physical facilities. The full-scale plant did not provide rapid mix or flocculation units. An additional difference was that sodium hydroxide was used for alkalinity control of Richmond-Sunset instead of lime as was used in the Southeast tests. These differences must be considered when comparing the dosages required for the Southeast tests and the Richmond-Sunset tests. For example, the rapid mix at the Richmond-Sunset plant was not as efficient as the pilot plant rapid mix and flocculators were nonexistent.

The sewage flow at the Richmond-Sunset Plant is primarily domestic sewage. Diurnal fluctuations from low to high of 4 to 1 are common. Low flow periods occur during the night and peak flow periods occur during the morning and early evening. The weekend flow is considerably higher than the weekday flow. The primary coagulant dosage requirement of the sewage increases and decreases with the strength of the sewage which, in turn, during dry weather generally varys with the flow. A higher dosage of alum, for example, was required during peak dry weather flows than during the nighttime low flows. The rain water diluted sewage from the combined sewer system presented difficult problems in coagulation control. The flow to the plant could increase as much as 400 percent in 30 minutes while the required dosage of the primary coagulant could decrease 80 percent during this same period. The range of the permissible dosage would also become extremely narrow during rainy periods. As little as 25 mg/l in dosage could separate an underdosage from an overdosage.

Richmond-Sunset Alum Tests-

The plant-scale operation at Richmond-Sunset began in September, 1973. The results are shown in Table 9-3. Alum was used as the primary coagulant, sodium hydroxide as the base chemical, and Calgon's WT-3000 anionic polymer as a coagulant aid. Under the direction of the plant personnel, the chemicals were added as follows:

Time	Alum mg/l	NaOH mg/l	Polymer mg/l
0100-1000	250	0	1
1000-1700	275	20	1
1700-0100	250	10	1

In November, when the pilot-scale filters and carbon columns were tested, it became evident that the sedimentation basin was not producing a filterable effluent. This was subsequently found to be due to a combination of sludge removal and coagulation problems. The possibility of anaerobic digester failure called a temporary halt to chemical treatment before the details of the problems could be determined.

Further testing with alum in April, 1974 indicated that, during this testing period, the weekday dosage requirement was as follows:

Time	Alum mg/l	NaOH mg/l	Polymer mg/l
0000-0600	200	20	1
0600-1200	350	30	1
1200-1800	300	25	1
1800-2400	350	30	1

DISCUSSION OF TEST RESULTS

The weekend peak flows and peak strength sewage required generally higher dosages. Weekend dosage requirements for the April test were as follows:

Time	Alum mg/l	NaOH mg/l	Polymer mg/l
0000-0700	200	20	1
0700-2400	375	35	1

During the rain weather flows, the dosage could change dramatically and the centrate turbidity and effluent alkalinity was monitored closely for correct dosage control. Generally, the chemical dosages required during the rain weather were as follows:

	Alum mg/l	NaOH mg/l	Polymer mg/l
RAIN WEATHER	25-150	10-25	1

The importance of the centrate turbidity in evaluating the coagulant performance cannot be over emphasized. The above values for dosage control served only as guidelines during the April test. The dosage was increased or decreased only if the centrate turbidity test indicated a need for change.

Richmond-Sunset Ferric Chloride Test-

In January 1974, ferric chloride was also tested as a primary coagulant on the plant-scale at Richmond-Sunset. Problems with coagulant control and sludge removal, similar to the alum test, were encountered. The range of the permissible

ferric dosage was more limited than with alum, particularv during rain weather flows. The general dosage required to produce a filterable effluent during this test was as follows:

Time	Ferric Chloride mg/l	NaOH mg/l	Polymer mg/l
0000-0600	150	30	1
0600-1200	200	50	1
1200-1800	175	40	1
1800-2400	200	50	1
RAIN WEATHER	10-50	10-25	1

Chemical coagulation with ferric was extremely difficult to control because of the problem of staining the effluent brown with an overdosage of the coagulant. For example, during periods of rain weather flow, the alkalinity of the influent wastewater will drop extremely low (40 mg/l). In jar tests with rain weather flow, it was noted that the range of the permissible dosage was less than 50 mg/l. For example, a dosage of 25 mg/l ferric would be an underdosage while a dosage of 75 mg/l would be an overdosage.

Richmond-Sunset Cationic Polymer Test-

A cationic polymer produced by the American Cyanamid Co., with the trade name Magnifloc 509-C, was also tested on pilot and plant-scale at Richmond-Sunset. This is a proprietary material. It is a liquid cationic polymer having a pH of 1.7 to 2.0 and a specific gravity of 1.03 to 1.045. It is reported to be biodegradable. This chemical, differing from the trivalent coagulants, does not combine with the alkalinity in the wastewater and no base chemical was necessary for alkalinity control.

DISCUSSION OF TEST RESULTS

A 3-day plant-scale test with 509-C was conducted in February 1974. The dosage was adjusted according to the centrate turbidity, but the general dosage required to produce a filterable effluent was as follows:

Time	509-C mg/l	Polymer mg/l
0000-0600	250	1
0600-2400	350	1

This 3-day plant-scale test occurred during a period of intermittant rain and the sewage was significantly weaker in strength than dry weather flows. Therefore, the dosage required during this period was lower than the dry weather requirement. This was indicated the last day of the test, when the 350 mg/l dosage did not produce a filterable effluent.

On the basis of the 3-day plant-scale test, further testing of 509-C on a pilot plant scale was considered necessary. The pilot plant test was held both during a period of rain weather flows and after a week without rainfall. All tests were conducted during an 8-10 hour daytime period. The rain weather conclusions are as follows:

1. During rainy weather the amount of solids in the combined sewage is too low to provide nuclei for the 509-C to coagulate and form floc particles. It is necessary to provide approximately 1 percent of the flow in recycled clarifier sludge for coagulation.

2. If the solids are recycled, a dosage of 250 mg/l is adequate to achieve coagulation and produce a filterable effluent during rainfall.

For dry weather flow, the dosage requirement for 509-C during the daytime period was 400 mg/l in the pilot plant. During weekend peak flow and sewage strength periods the required dosage to produce a filterable effluent was 450 mg/l.

At present, 509-C is more than 2.5 times as expensive as alum. In an attempt to lower the daily chemical cost, a combination of alum and 509-C was tested on pilot scale. It was determined in jar tests that the alum had to be added first, followed by the 509-C. The jar tests also indicated that the required dosage of one or the other chemical alone must be approached before the combination would produce a filterable effluent.

The pilot tests were conducted during the rain weather flows and the overall dosage requirement was low. Varying dosages of 100 to 150 mg/l of alum were required with 200 mg/l of 509-C and 1 mg/l of anionic polymer. It became evident during the test that it would be possible to overdose with the alum during rainwater flows. The addition of a base chemical for alkalinity control would also be required.

Flocculation

The correlation between pilot plant flocculation and prototype flocculation should be fair.

There is some trade-off between the amount of polymer which can beneficially be used to increase the speed of

floc formation and the amount and type of flocculation equipment available. The addition of coagulant chemicals to wastewater requires adequate flocculation in order to form particles that are large enough to settle rapidly. As outlined in the Design and Operation Sections, mechanical flocculators were used in the pilot plant to mix the small, coagulated particles into larger particles after the addition of the anionic polymer as a coagulant aid. The plant-scale tests at Richmond-Sunset have demonstrated, however, that good coagulation can be obtained without mechanical flocculators during periods of dry weather flow. Under these conditions, the high chemical dosage required in combination with the relatively high solids content of the wastewater provides such a large mass of particles that mechanical flocculation is not necessary.

During periods when the sewage is diluted with rain water, the solids content, alkalinity, and dosage requirement of the sewage drop appreciably. Coagulation is weak and mechanical flocculation may be necessary in order to form a settleable floc. Futher plant-scale testing during rain water flow with varying amounts of solids recycle should be done before finalizing a decision to eliminate mechanical flocculators from the Richmond-Sunset chemical process design.

While the cost estimates in Section X for the physical/chemical process trains for the Southeast plant include flocculators, the experience at Richmond-Sunset raises a question as to the necessity of this equipment. Elimination of the flocculators would reduce the capital cost of the physical/chemical process trains by less than 2.5 percent. This small fraction would make no significant difference

in the comparison of the physical/chemical trains with the biological trains. However, if flocculators were required at Richmond-Sunset, the area which they would occupy would result in a major reduction in the area available for sedimentation basin construction.

Figure 9-4 shows the size of dry weather alum floc particles in the pilot plant mechanical flocculator at Richmond-Sunset.

Sedimentation

As indicated in the Operations Section, the circular sedimentation tanks used in the pilot plant at the Southeast for sedimentation of chemically coagulated solids in the alum and ferric chloride systems were normally operated at a sedimentation overflow rate of 1000 gpd/sq ft (41 cu m/day/sq m). It was also possible to produce a filterable effluent at rates as high as 2000 gpd/sq ft (42 cu m/day/sq m). A note of caution is required, however, in extrapolation of plant-scale overflow rates and detention times from pilot scale since it is essentially impossible to establish true similitude between pilot and plant-scale sedimentation tanks.

At Richmond-Sunset, both plant-scale rectangular and pilot plant circular sedimentation tanks were tested at differing sedimentation overflow rates. During the initial plant-scale alum test, the maximum overflow rate that would produce a filterable effluent was thought to be less than 1000 gpd/sq ft (41 cu m/day/sq m). It was determined in the second test, however, that during the initial testing there had been coagulation control and solids removal problems which lowered the permissible overflow rate. During the

second alum test, overflow rates as high as 1600 gpd/sq ft (65 cu m/day/sq m) were tested. At this high rate, the solids carryover into the effluent was high enough to shorten filter runs. It was not possible to consistently produce a filterable effluent at overflow rates higher than 1200 gpd/sq ft (49 cu m/day/sq m) during the second plant-scale test with alum.

The plant-scale ferric chloride test was similar to the initial alum test because coagulation control and solids removal problems lowered the maximum overflow rate. On the first day of the test the permissible overflow rate was 1200 gpd/sq ft (49 cu m/day/sq m), but as the test continued the permissible rate continued to decrease. This was subsequently deduced to be a solids removal problem rather than an overflow rate limitation. From the testing at Southeast, the permissible overflow rates for the ferric chloride and alum systems were identical. If any differences could be assumed, it seemed that the ferric chloride system could have been operated at a slightly higher overflow rate than the alum system.

In the pilot-scale Magnifloc 509-C test, a filterable effluent was produced at the 1600 gpd/sq ft (65 cu m/day/sq m) overflow rate. There was also an indication that the plant sedimentation basins could produce a filterable effluent at this same rate. On the pilot-scale, overflow rates as high as 2000 gpd/sq ft (82 cu m/day/sq m) produced an effluent meeting SWRCB ocean discharge requirements and the plant scale test indicated a similar satisfactory result.

The pilot sedimentation basin could be operated at a maximum overflow rate of 1000 gpd/sq ft (41 cu m/day/sq m) when the combination of alum and 509-C was tested. It should be noted, however, that this test was conducted

during a rain weather period and sedimentation sludge was not recycled to the headworks of the pilot plant. It was indicated in jar tests that the recycle of sludge produced a denser, better settling floc than could be produced without recycle. Thus, if solids had been recycled, the maximum overflow rate possible by using the alum-509-C combination would have been slightly higher. The following table is a summary of the sedimentation basin overflow rates that are possible with the various chemical coagulants:

Coagulant	gpd/sq ft (0.0408 cu m/day/sq m) Overflow Rate	
	Effluent Meeting SWRCB Ocean Standard	Filterable Effluent
Alum	1600	1200
Ferric Chloride	1600	1200
Magnifloc 509-C	2000	1600

Effect of Saltwater Intrusion

The San Francisco Department of Public Works has long recognized the beneficial effect on coagulation of adding seawater to the sewage. Even though brief periods of rain were encountered during the North Point-Southeast testing, no difficulty was

encountered in maintaining adequate coagulation with the constant and relatively high doses of ferric chloride and alum which were used throughout the test. Even though problems were encountered with sedimentation basin upset as a result of changes in the saltwater content in the sewages, coagulation remained excellent during these periods of upset. The upsets were physical in nature rather than chemical. Testing at Richmond-Sunset demonstrated the problems which can be anticipated when the sewage is diluted by stormwater and saltwater is not present. Under these conditions, the range of satisfactory coagulant dosage is markedly narrowed and proper control becomes extremely difficult; the proper dosage can fluctuate both widely and rapidly making chemical coagulation control with presently available technology extremely difficult if not impossible.

It has been previously pointed out that it is essential to eliminate the variations in sewage density if tertiary physical/chemical processes are to be used. However, if the variations in density are eliminated by eliminating the saltwater, it appears that the problems of coagulation control experienced at Richmond-Sunset will be substituted for the density variation problems encountered in the treatment of the North Point and Southeast sewages. Since no satisfactory solution to this dilemma presents itself at this time, it is suggested that consideration of the problem be held in abeyance pending a decision as to whether or not physical/chemical treatment is a practical process for the treatment of San Francisco sewage.

DISCUSSION OF TEST RESULTS

Foaming

Considerable difficulty was encountered with foaming of chemically coagulated sewage. This was true regardless of the chemical used or the sewage treated. As discussed in the operation section, this problem occurred when the propellers in the rapid mix tanks were at an angle such that a vortex was created; the aeration that resulted from this vortex caused a layer of foam 3 inches to 1 foot thick to build up in the flocculation basin.

At Richmond-Sunset, during the plant scale tests, large amounts of foam were formed in the effluent channel from the aeration that occurred in the effluent launder (Figure 9-5). Some evidence of blowing foam was observed at the Mile Rock outfall during the alum test. Since the alum foam is white, it would be difficult to differentiate between this foam and natural sea foam, except by a trained observer. The color of foam produced by ferric chloride makes its presence quite obvious. If chemicals are used for coagulation, the above experience dictates that, insofar as possible, conduits handling the coagulated wastewater should be designed to avoid aeration.

Filtration and Carbon Columns

The extrapolation of pilot filters and activated carbon adsorption data to full scale is fairly reliable. The pilot plant filters are full-scale units in the vertical dimension and, therefore, results from the filtration studies are directly applicable to prototype design in terms of filter

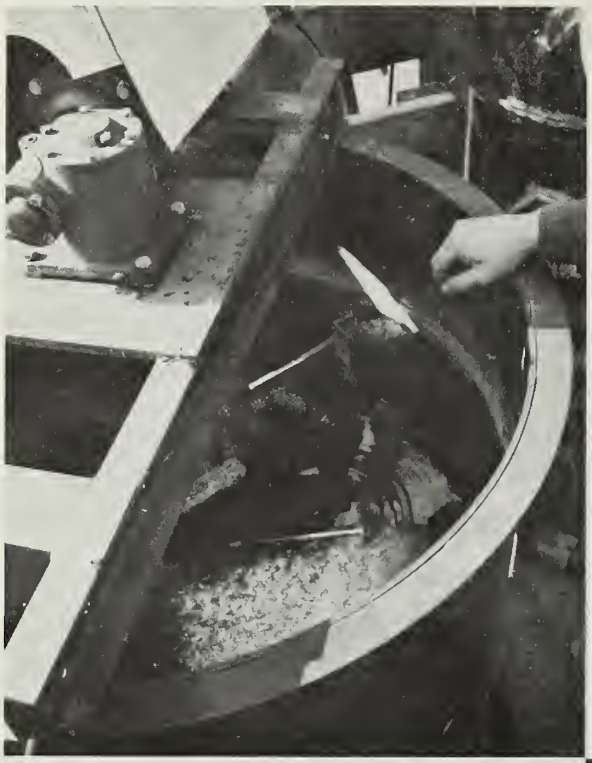


FIGURE 9-4

RICHMOND-SUNSET
ALUM FLOC

FIGURE 9-5

RICHMOND-SUNSET
FOAM IN EFFLUENT CHANNEL

loading, length of filter run, and quality of effluent produced. Because of the problems encountered in backwashing small diameter filters, the amount of backwash water measured during the pilot plant operation does not truly reflect the amount which would be necessary in the full-scale plant. Extensive data are available from full-scale units and provide a better source of this information than do the pilot plant data.

The pilot activated carbon units generally will provide good results if they can be operated for a period of time long enough to bring the carbon to exhaustion and can be operated as they would be in the full-scale plant.

CONSTITUENT REMOVAL

A major unanswered question at the start of the study was the ability of the various tertiary physical/chemical processes to meet the BOD removal requirements of either the EPA or the RWQCB tentative Bay Discharge Requirements. The Southeast test showed that only marginally can the tertiary physical/chemical trains adequately remove BOD from the Southeast wastewater. The amount of BOD refractory to carbon approaches the limits of the standards. The data from the North Point-Southeast testing indicate that tertiary physical/chemical treatment again can only marginally meet these requirements when treating the blended sewages.

On Figure 9-6 are shown BOD data developed from San Francisco plant operating records for 1972 and 1973. The plotted data were synthetically developed based on the

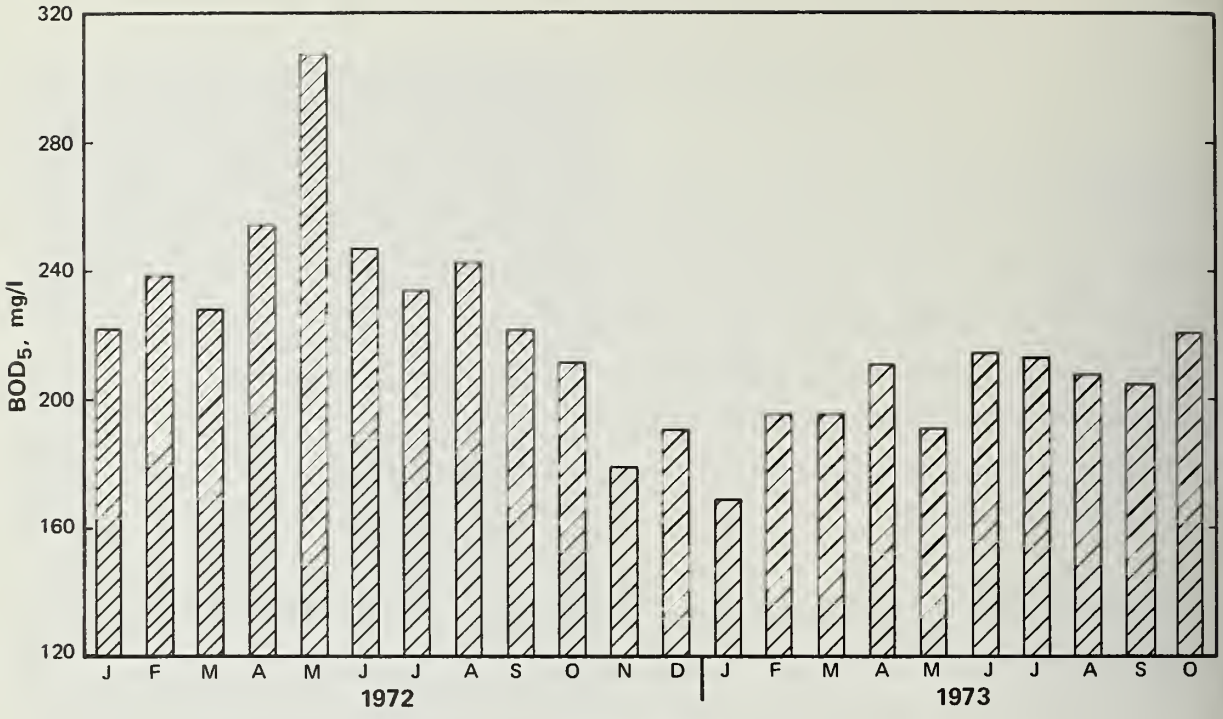


FIGURE 9-6

AVERAGE MONTHLY BOD_5
75% NORTH POINT + 25% SOUTHEAST

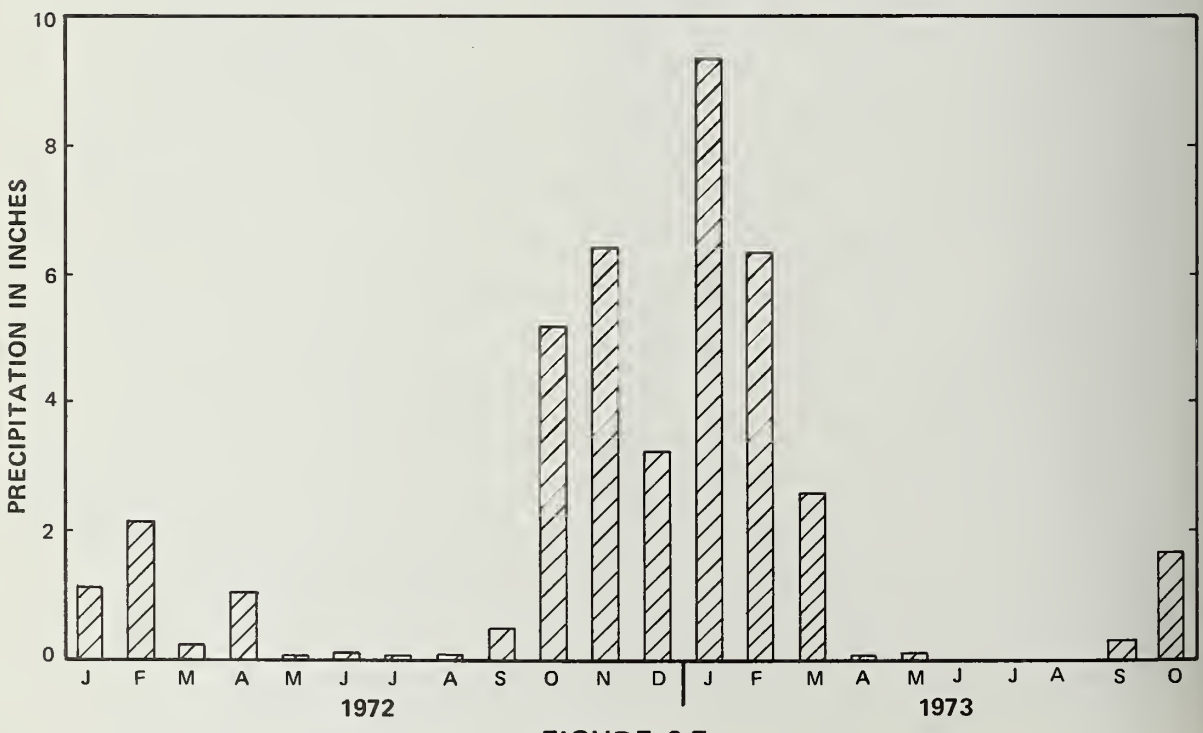


FIGURE 9-7

SAN FRANCISCO
MONTHLY PRECIPITATION

assumption that the sewage ultimately treated at the Southeast plant will be made up of 75 percent North Point sewage and 25 percent Southeast sewage. These average monthly BOD data for 1972 and 1973 indicate that BOD values higher than those tested in September and October 1973 may occur during some months of a year of less rainfall than that experienced in 1973. Figure 9-7 shows the monthly San Francisco rainfall during 1972 and 1973.

The potential for sewages of greater strengths than those tested suggest that careful consideration be given to the selection of candidate processes for full-scale construction.

The initial testing with alum at Richmond-Sunset indicated that a tertiary physical/chemical process could meet the EPA BOD Standards. As stated previously, however, this test was held during a period of rain weather flows, and the influent BOD values were near their historically recorded lows. Later testing, with sewage of higher BOD, indicated that a TP/C process would either fail to meet the EPA BOD Standard of 30 mg/l or at best would only be marginally successful when treating sewage of this strength.

NORTH POINT-SOUTHEAST AND SOUTHEAST BOD RESULTS

On Table 9-8 is shown a summary of the 50 percent BOD values developed under the two test programs at the indicated stations. Stations 14, 21, and 28 are sedimentation basin effluents; stations 16, 23, and 30 are carbon column effluents downstream from filtration and the indicated chemical coagulants. It is interesting to note that the

TABLE 9-8

PHYSICAL/CHEMICAL PROCESSES
BOD_5, mg/l
(50% VALUES)

STATION	COAGULANT	SOUTHEAST	NORTH POINT–SOUTHEAST	
14	Ferric	73	34	Sedimentation Effluent
21	Lime	44	32	
28	Alum	62	33	
16	Ferric	29	14*	Carbon Column Effluent
23	Lime	26	22	
30	Alum	23	6*	

*Carbon columns acting as anaerobic biological filters.

TABLE 9-9

RICHMOND-SUNSET
NOVEMBER 1973 ALUM TEST DATA

DATE 1973	BOD, mg/l RAW	BOD, mg/l SED. BASIN	BOD, mg/l FILTER EFFLUENT	BOD, mg/l CARBON EFFLUENT	TSS, mg/l RAW	TSS, mg/l SED. BASIN	TSS, mg/l FILTER EFFLUENT	TSS, mg/l CARBON EFFLUENT
11-7	141	34	33	4	222	16	8	4
11-8	150	34	37	10	180	46	19	12
11-10	132	17	22	2	163	52	7	1
11-11	87	33	16	6	106	45	14	2
11-12	132	36	10	2	159	44	10	8
11-13	192	39	25	5	144	35	20	4
11-14	158	34	24	4	166	27	5	3
11-15	145	30	29	5	186	26	4	1
11-16	189	32	21	4	112	40	9	2
11-17	114	34	22	4	116	24	4	0.5
11-18	139	24	25	3	125	16	3	0.2
AVERAGE	144	31	24	4	153	34	9	3
AVERAGE % REMOVAL	–	78	83	97	–	78	94	98

results from the Southeast test are essentially the same for all three carbon columns. This is logical and to be anticipated since the removal mechanism is one of adsorption preceded by particulate coagulation regardless of which chemical is used. One would anticipate slightly better results from the lime simply because it was preceded by ferric chloride coagulation and because the heavier calcium carbonate sludge produced is less subject to upset than that produced by the alum or ferric processes.

In the case of the North Point-Southeast data, the results, if examined only superficially, are illogical. As an example, the BOD at Point 23 which is downstream from both the ferric chloride clarifier and the lime clarifier is greater than that at Point 16, which has been given only ferric chloride coagulation ahead of filtration and carbon. Further, the BOD at Point 30 where the waste has received only alum coagulation is considerably lower than that at either Point 16 or 23. However, it must be remembered that the filters and carbon colums in both the process trains serving Point 16 and Point 30 were subject to periodic interruptions as a result of sedimentation basin upsets caused by changes in influent sewage density. These down periods coupled with a relatively high BOD loading on the carbon columns in these trains resulted in the early development in these carbon columns of anaerobic conditions which in turn caused odors in their effluents.

As previously noted, it was necessary to feed sodium nitrate to these carbon columns for odor control after only a few days of operation. The data shown in Table 9-2 and the daily nitrogen data shown in Appendix K from these stations

show that the carbon columns in both the trains serving Point 16 and Point 30 were operating as anaerobic filters throughout most of the North Point-Southeast test. It can be concluded from the data shown in Table 9-8 that the 50 percent value for BOD from any of the tertiary physical/ chemical processes tested when treating a proportionally blended North Point-Southeast sewage will be very close to or perhaps slightly exceed the value shown for Point 23.

RICHMOND-SUNSET

The BOD and suspended solids removals, in Table 9-3, for the first alum test during wet weather showed very low amounts of soluble BOD refractory to activated carbon treatment. However, Table 9-10 indicates normally the raw BOD will be much higher. To summarize the tables, the influent BOD during the November testing averaged 144 mg/l. The sedimentation basin effluent BOD was only 31 mg/l and the effluent after activated carbon treatment was 4 mg/l. However, the normal monthly average recorded BOD for the influent during dry weather flows are considerably greater than 144 mg/l. Thus, there is the probability that the activated carbon removal efficiency will not be adequate to meet the EPA 30 mg/l standard during the dry weather periods.

Heavy rainfall was experienced during the first day of the Magnifloc 509-C pilot test in March 1973 (Table 9-11). The raw sewage BOD was only 106 mg/l. The effluent after activated carbon treatment on this day had a BOD of 10 mg/l, which is similar to what was experienced during the November 1973 alum test. The Magnifloc test was halted on 8 March and did not resume until 14 March. After 8 March,

TABLE 9-10

RICHMOND-SUNSET
HISTORICAL BOD-TSS
INFLUENT DATA

YEAR MONTH	INFLUENT BOD MEAN MONTHLY mg/l 1973	INFLUENT TSS MEAN MONTHLY mg/L 1973
January	181	139
February	145	139
March	169	120
April	213	173
May	211	167
June	226	182
July	233	167
August	225	171
September	260	179
October	238	193
November	208	167
December	214	155

it did not rain until after the test was completed on 18 March. The influent, 8-hour daily composite BOD averaged 240 mg/l for the test period. The average BOD for the sedimentation effluent was 90 mg/l and the activated carbon effluent averaged 29.6 mg/l for these 5 days.

Hourly BOD data from the second plant scale alum test are shown in Table 9-12. These data were taken on 7 April 1974 and it had not rained since 5 April. The flow-proportioned influent BOD was 234 mg/l and the sedimentation basin effluent BOD was 90 mg/l, which is the same result experienced during the Magnifloc 509-C test. It is considerably higher than the 31 mg/l result experienced in November. It is reasonable to assume the filters and activated carbon will not reduce the 90 mg/l BOD from the alum test to a level lower than that experienced during the Magnifloc test. As stated previously, the activated carbon effluent during the dry weather 509-C test averaged 29.6 mg/l.

Since reliable historical average influent BOD values are as high as 260 mg/l, it is probable that a tertiary physical/chemical plant will fail to consistently meet the EPA 30 mg/l BOD requirement when treating Richmond-Sunset sewage.

The combined effluent, however, from a 27 mgd (1.18 cu m/sec) primary physical/chemical plant at Richmond-Sunset and a 100 mgd (4.38 cu m/sec) biological treatment plant at Southeast might marginally meet the EPA Discharge Requirements.

Phosphate Removal-

At the Southeast and Richmond-Sunset treatment plants phosphate removals of greater than 97 percent were recorded for orthophosphate and total phosphate, when trivalent

TABLE 9-11

RICHMOND-SUNSET
MAGNIFLOC 509-C TEST DATA

	BOD_5, mg/l				TSS, mg/l			
1974	INFLUENT	SED. BASIN EFFLUENT	FILTER EFFLUENT	CARBON EFFLUENT	INFLUENT	SED. BASIN EFFLUENT	FILTER EFFLUENT	CARBON EFFLUENT
3-7	106	95	56	10	98	53	14	1.0
3-8	182	80	73	27	323	27	3.2	0.7
3-14	195	98	74	22	159	45	12.5	4.0
3-15	253	114	95	33.2	162	35	18	14
3-16	267	110	98	33.7	130	37	17	14
3-17	244	64	55	31	212	29	23	13
3-18	239	63.4	61.4	28.1	246	24	6	11
AVERAGE	212	89	73	26	190	36	13	7
AVERAGE % REMOVAL	–	58	66	87	–	66	72	91

TABLE 9-12

RICHMOND-SUNSET
PLANT SCALE SEDIMENTATION BASIN ALUM TEST

7 APRIL 1974 TIME	OVERFLOW gpd/sq.ft.*	BOD INFLUENT mg/l	BOD EFFLUENT mg/l
0000	975	186	46
0100	800	240	153
0200	510	206	147
0300	400	182	147
0400	400	151	141
0500	475	145	116
0600	400	150	68
0700	—	211	49
0800	725	126	46
0900	1,220	221	38
1000	1,580	345	135
1100	1,580	285	88
1200	1,540	271	89
1300	1,440	150	89
1400	1,200	221	70
1500	1,220	232	59
1600	1,170	186	151
1700	1,170	267	76
1800	1,220	207	67
1900	1,270	249	69
2000	1,270	262	50
2100	1,220	294	55
2200	1,220	245	54
2300	1,220	217	60
FLOW WEIGHTED AVERAGE		234	90
NONPROPORTIONED AVERAGE		197	85

* x 0.0408 = cu#m/day/m^2

metal coagulants were used. Average effluent values were less than 0.06 mg/l for orthophosphate and 0.2 mg/l for total phosphate.

The percentage removal for orthophosphate was not as great when the cationic polymer was tested at Richmond-Sunset. As shown in Appendix L, the average removal of orthophosphate from raw sewage to carbon column effluent was 40 percent when Magnifloc 509-C was used as the primary coagulant. This low percentage indicates that the removal was mainly particulate phosphate and the Magnifloc 509-C does not combine with the soluble phosphate to any appreciable extent.

Sludge Volume

Sludge disposal is one of the more significant factors in governing the selection of the proper chemical coagulant for a physical/chemical system. Unfortunately, the actual weight and volume of the sludge produced with chemical coagulation is very difficult to measure on plant or pilot scale. Different methods were attempted at Southeast and Richmond-Sunset to determine an approximate value for the amount of sludge being produced, but the approximations tended to be of questionable reliability. As a result, the theoretical approximation was used to determine the amount of sludge being produced with alum and ferric chloride. Bench-scale testing with Richmond-Sunset wastewater has shown a high degree of correlation between the theoretical values and the results measured in the laboratory.

DISCUSSION OF TEST RESULTS

No theoretical work has been done to determine the amount of sludge produced from the addition of Magnifloc 509-C to wastewater. Bench-scale testing was used to determine an approximation for this value, but the deviations among the test results were large. Approximately 10 percent by weight of the Magnifloc 509-C was produced in the resulting sludge. This is the approximation used by the American Cyanamid Co., but further research is needed in this area.

Anaerobic Digestion

Throughout the San Francisco Pilot Plant Study, one of the major questions was the ability of anaerobic microorganisms to adapt to the sludge that was produced from high dosages of alum or ferric chloride. At the present time, the sludge that is produced at the three San Francisco water pollution control plants is stabilized through the anaerobic digestion process. If the chemically dosed sludge could not be treated in anaerobic digesters, an entirely different solids disposal system would be required. Unfortunately, there is little data available on the digestion of sludge produced at the high dosages required for coagulation of the San Francisco sewages and there was no alternative but to develop an experimental program.

During the plant-scale chemical testing at Richmond-Sunset, the sludge that was produced through chemical coagulation was pumped to the existing anaerobic digesters for stabilization. There are two existing digesters operated in series. The primary digester has a capacity of 2,100,000 gallons (8 million liters). The secondary digester has a capacity

of 1.1 million gallons (4.2 million liters). In the first alum test, the digester gas production per pound of volatile solids added to the digester decreased by 40 percent within a few days after the start of the alum test and held at this lower rate for approximately 6 weeks. Then, during a period of rainy weather, the gas production continued to decrease to the point where it appeared possible that the digester would fail. The alum chemical treatment was halted at this time and the normal primary sludge was again pumped to the digesters. The gas production immediately began to increase and, after 4 weeks, it was near previous levels.

The second alum test was of 10 days duration in April 1974. Its primary purpose was to study coagulation control, overflow rates and sludge removal. The time period may have been too short to obtain reliable data from the anaerobic digester since, under present operating conditions, the detention time in the primary digester is approximately 35 days. Thus, less than one-third of volume was replaced with alum-treated sludge. However, the gas production per pound of volatile solids decreased by 25 percent during the test. This leads to the speculation that the adverse effect is of a physical rather than a toxic nature.

The plant-scale ferric chloride test was conducted for 15 days. The gas production per pound of volatile solids added decreased by approximately 25 percent during the ferric test.

During the 3-day Magnifloc 509-C test, no change in the gas production was noticed.

DISCUSSION OF TEST RESULTS

STANFORD ANAEROBIC DIGESTER STUDY

When the difficulty with treating chemically-treated sludge in the anaerobic digestion process was noted, a program was initiated at Stanford University to study this problem. Under the direction of Dr. Perry McCarty, eight laboratory-scale anaerobic digesters were tested with the sludge produced from Richmond-Sunset sewage using various coagulants and coagulant dosages. The gas production, volatile acids, and alkalinity were recorded daily in each digester. The detention time in the digesters was 15 days. The sludge was produced by coagulating the raw sewage with chemicals in 55-gallon drums (208 liters). For the first section of the study, alum dosages of 150, 200, and 250 mg/l were added to the sewage. Later, the 150 mg/l sample was replaced with sludge coagulated with 325 mg/l of alum. Ferric sludges produced from 100, 150, and 200 mg/l of ferric chloride and one dosage of 300 mg/l of Magnifloc 509-C were also tested. One sample of untreated primary sludge was used as the control sludge.

The studies are presently continuing at Stanford University. Samples with increased dosages of Magnifloc 509-C and alum are being tested. The gas production compared to varying detention times is also being studied. A copy of the initial study report is Appendix H-2. The tentative conclusions presented in the report are:

> After 61 days of digestion, statistically significant decreases in digester performance were noted when sludges derived from alum-dosed (200-325 ppm) and $FeCl_3$ -dosed (100-200 ppm) wastewater were fed, semicontinuously, to

laboratory digesters operated at 15-day detention times. Performances varied from 80-90% of the control digester, with no apparent toxicity problems evident, such as volatile acid build-up or pH difficulty.

Even in the observed cases of greatest relative efficiency deficit, the treatment efficiency, if one were to ignore the control, is good. The least efficient reactor studied, that utilizing the $FeCl_3$ 200 ppm-derived sludge, for example, still evidenced about 8 cu ft of gas per lb of volatile solids added, which falls within the range considered "typical" (8-12 cu ft/lb VS added) for municipal digesters (3). Greater than 50% volatile solids destruction was observed for all cases where steady-state conditions were reached in the effluent.

Whether the statistically significant decreases in efficiency are operationally significant will depend, in part, upon the subsequent disposal methods available for the digested sludge, as well as the extent to which the remaining volatile solids are capable of being further degraded after disposal (thus creating nuisance).

The extent to which the unutilized solids content difference between control and dosed sludges can be subsequently degraded if given sufficient time, could be determined by varying either the detention times of reactors, or by allowing a set of batch reactors to incubate for a long time, to approximate the degradation possible with greatly increased detention time. The results from such a study could shed some light on the mode of action of chemical coagulants on digester performance, and possibly answer the question of whether the effect is a kinetic one or not.

RELATIVE CONSTITUENT REMOVAL

Process Reliability

On Tables 9-13 and 9-14 are recorded coefficients of reliability for the indicated process points for

TABLE 9-13

SOUTHEAST

PROCESS RELIABILITY[1][2] COMPARISON

CONSTITUENT	STANDARD mg/l	COEFFICIENT OF RELIABILITY									
		CONV. A/S		HPO A/S		FERRIC CHLORIDE COAGULATION				ALUM COAG.	
SAMPLE POINT		5	9	10	12	14	16	21	23	28	30
METALS[3][5]											
Arsenic	0.01	2	8	2	8	8	8	8	8	8	8
	0.02	5	18	5	18	18	18	18	18	18	18
Cadmium	0.02	41.2	–	33.5	–	33.5	–	20.1	–	37	–
	0.03	63	–	52	–	52	–	31	–	57	–
Chromium	0.005	- 1.2	- 1	- 1.4	- 1.1	- 1.2	- 1	- 1.1	- 1	- 1.2	- 1.1
	0.01	- 1.1	- 1	- 1.4	- 1.1	- 1.1	- 1	- 1	- 1	- 1.2	- 1
Copper	0.2	7.9	18.5	8.8	23.4	10.6	10.8	21.9	34.5	5.8	20.1
	0.3	12	29	14	36	17	17	34	53	9.4	31
Cyanide	0.1	8	–	8	–	0.8	1.6	1.3	2	0.4	1.6
	0.2	18	–	18	–	2.8	4.4	3.7	5.3	1.9	4.4
Lead	0.1	1.4	7.3	2.9	9	2.8	8.5	9	14.8	3.5	5.3
	0.2	4	16	7	19	6.8	18.5	19.5	31.5	8.3	12.0
Mercury	0.001	-1	-1	-1	-1	-1	-1	-1	0	-1	-1
	0.002	–	4.0	-0.9	-0.7	0.1	0.7	4.0	–	-0.9	1.5
Nickel	0.1	- 0.2	.5	- 0.5	0.4	- 0.2	- 0.1	1.7	3.4	0	2
	0.2	0.9	2.3	0.3	2.1	0.9	1.1	4.7	8.0	1.3	5.3
Silver	0.02	1.8	5.3	3.5	8.5	3.2	12.1	8.5	12.6	2.3	6.6
	0.04	4.7	12	8.5	18.5	7.7	26	18.5	27	5.8	14.6
Zinc	0.3	- 0.6	- 0.1	- 0.8	- 0.6	- 0.2	- 0.5	5.7	6.5	- 0.4	2.2
	0.5	- 0.3	0.5	- 0.7	0.3	0.4	- 0.1	10.2	11.7	0.1	4.4
CHEMICAL											
BOD_5 [4]	30	- 0.1	3.2	0.7	1.6	- 1	- 0.6	- 0.9	- 0.6	- 0.9	- 0.6
[4]	45	0.4	5.4	1.8	3.1	- 0.9	- 0.3	- 0.5	- 0.3	- 0.8	- 0.3
Oil & Gr. [3]	10	0.7	1.9	- 0.4	- 0	0.5	- 0.4	0.7	- 0.7	- 0.8	- 0.6
[3]	15	1.6	3.4	- 0.2	0.5	1.3	- 0.1	1.6	- 0.5	- 0.6	- 0.4
[5]	5	- 0.2	0.4	- 0.7	- 0.5	- 0.3	- 0.7	- 0.2	- 0.8	- 0.9	- 0.8
Phenols [3][5]	0.5	11.7	997	13.2	498	0.4	198.6	0.5	997	0.5	198.6
	1.0	25	–	28	998	3	398	3.2	1997	2.9	399

NOTES:
(1) Relative reliability ranges from a maximum at infinity (∞) to a minimum at the lowest negative number.
(2) Low or negative numbers do not necessarily indicate failure to meet the indicated standard.
(3) SWRCB Ocean Policy.
(4) Environmental Protection Agency Secondary Treatment Standards.
(5) RWQCB Tentative Bay Standards.

TABLE 9-13 (Cont'd)

SOUTHEAST
PROCESS RELIABILITY[1][2] COMPARISON

CONSTITUENT	STANDARD mg/l	COEFFICIENT OF RELIABILITY									
		CONV. A/S		HPO A/S		FERRIC CHLORIDE COAGULATION				ALUM COAG.	
SAMPLE POINT		5	9	10	12	14	16	21	23	28	30
NUTRIENTS[3][5]											
Ammonia	40	2.4	2.5	2.7	2.6	–	2.5	–	3.6	–	1.6
	60	4.3	4.4	5.1	5.0	–	4.8	–	6.7	–	3.4
PHYSICAL											
Floatables [3]	1.0	-1	-0.7	-1.1	0.2	-0.9	-0.3	-1	-0.3	-0.9	-0.7
	2.0	-0.9	-0.4	-0.9	1.5	-0.7	0.6	-0.9	-0.5	-0.7	-0.3
Settleable Solids[3][5]	0.1 ml/l	0	0	0	0	0	0	0	0	0	0
[3]	0.2	–	–	–	–	–	–	–	–	–	–
Suspended Solids [3]	50	0.2	2.1	-0.1	4.2	-0.2	2.4	3.6	4.3	-0.3	2
[3]	75	1.0	3.7	0.7	6.9	0.3	4.2	6.0	7.0	0.2	3.6
[4]	45	0.1	1.8	-0.2	3.7	-0.3	2.0	3.1	3.7	-0.4	1.6
[4]	30	-0.4	0.8	-0.7	2.1	-0.7	1	1.6	2.1	-0.7	0.6
[5]	15	-0.9	-0.1	-1.2	0.5	-1	-0.1	0.1	0.4	-0.9	-0.4
Turbidity [3]	50	3.2	3.8	1	8.3	1.6	7	2.5	15.8	0.7	0.7
(FTU) [3]	75	5.6	6.2	2.3	13.0	3.5	11.1	4.5	24.4	1.9	1.6
[5]	10	-0.7	-0.1	-1.1	0.6	-1.6	0.4	-0.6	2	-1.2	-0.8
BIOASSAYS											
Toxicity [3]	2.0	-0.2	–	0.9	0.0	-0.3	–	–	1.7	-1.0	-0.1
(tu) [3]	1.5	-0.4	–	0.4	-0.2	-0.5	–	–	1.0	-1.0	-0.3
TICH [3][5]	0.002	4.0	8.5	1.4	7.0	3.9	18.7	1	15	3.9	15.1
	0.004	9.5	18.1	3.9	15.1	9.0	38.3	3.0	31.2	8.9	31.3

TABLE 9-14

NORTH POINT-SOUTHEAST
PROCESS RELIABILITY COMPARISON

CONSTITUENT	STANDARD mg/l	COEFFICIENT OF RELIABILITY									
		CONV. A/S		HPO A/S		FERRIC CHLORIDE COAGULATION				ALUM COAG.	
SAMPLE POINT		5	9	10	12	14	16	21	23	28	30
METALS[3][5]											
Arsenic	0.01	2.3	10.4	2.1	2.3	2.2	3.9	4.0	11.3	5.9	- 0.4
	0.02	5.9	23	5.5	6.0	5.7	9.3	9.6	25	14	0.2
Cadmium	0.02	0.6	–	32	62	15	29	–	–	60	67
	0.03	1.5	–	50	96	23	44	–	–	93	102
Chromium	0.005	-1.1	-1.3	-1.6	-1.4	-1.4	-1.2	-1.1	-1.2	-1.6	-1.2
	0.01	- 1.0	-1.2	-1.6	- 1.3	-1,3	- 1.1	-1.0	- 1.1	-1.5	- 1.1
Copper	0.2	3.5	- 0.4	3.7	15	13	0.9	56	- 0.4	0.4	- 0.4
	0.3	5.8	- 0.1	6.2	23	20	1.8	85	- 0.1	1.2	- 0.1
Cyanide	0.1	–	–	5.4	–	1.4	1.0	0.3	1.9	0.8	1.6
	0.2	–	–	12.6	–	4.1	3.3	1.8	5.1	2.8	4.6
Lead	0.1	1.9	2.7	- 0.1	13	6.0	6.4	8.9	–	1.8	14
	0.2	5.1	6.6	1.0	28	11	14	19	–	4.8	29
Mercury	0.001	-1.0	0	- 1.0	- 1.0	- 1.0	-1.0	- 1.0	0	- 1.0	-1.0
	0.002	- 0.6	–	- 0.6	0.4	2.6	0.4	- 0.7	–	- 0.6	- 0.1
Nickel	0.1	2.6	0.6	0.5	2.6	0.3	- 0.5	5.2	4.4	2.1	1.0
	0.2	7.5	2.5	2.5	7.3	2.2	0.1	12	11	5.8	3.3
Silver	0.02	0.8	- 0.7	1.0	6.0	4.1	0.4	37	2.0	1.2	5.4
	0.04	2.6	- 0.3	3.0	13	9.5	1.8	77	5.1	3.6	12
Zinc	0.3	- 0.7	0.5	- 0.9	- 0.2	- 0.6	0.8	0.8	7.6	0.2	-0.3
	0.5	- 0.1	1.6	- 0.4	1.1	- 0.1	2.1	2.0	13	1.2	0.2
CHEMICAL											
BOD_5 [4]	30	- 0.4	6.4	2.6	2.1	- 0.7	- 0.3	- 0.6	- 0.5	- 0.9	0.1
[4]	45	- 0.1	10.2	4.7	3.8	-0.5	0.1	- 0.4	0.2	- 0.6	0.6
Oil & Gr. [3]	10	0.5	- 0.4	- 0.3	0.9	0.7	1.2	0.7	2.5	0.6	1.8
[3]	15	1.3	0.0	0.1	1.9	1.6	2.2	1.6	4.3	1.4	3.3
[5]	5	-0.2	- 0.7	- 0.7	- 0.1	- 0.1	0.1	- 0.2	0.8	- 0.2	0.4
Phenols [3][5]	0.5	51	170	31	293	7.4	165	4.3	293	5.4	207
	1.0	104	342	63	587	16	332	10	586	12	415

NOTES: (1) Relative reliability ranges from a maximum at infinity (∞) to a minimum at the lowest negative number.

(2) Low or negative numbers do not necessarily indicate failure to meet the indicated standard.

(3) SWRCB Ocean Policy.

(4) Environmental Protection Agency Secondary Treatment Standards.

(5) RWQCB Tentative Bay Standards.

TABLE 9-14 (Cont'd)

NORTH POINT-SOUTHEAST
PROCESS RELIABILITY COMPARISON

CONSTITUENT	STANDARD mg/l	COEFFICIENT OF RELIABILITY									
		CONV. A/S		HPO A/S		FERRIC CHLORIDE COAGULATION				ALUM COAG.	
SAMPLE POINT		5	9	10	12	14	16	21	23	28	30
NUTRIENTS(3)(5)											
Ammonia	40	9.0	22	5.1	4.5	–	4.0	–	3.7	–	4.6
	60	14	34	9.2	4.1	–	7.4	–	6.7	–	8.5
PHYSICAL											
Floatables (3)	1.0	0.3	3.5	0	5.0	2.0	2.0	0.8	8.0	1.6	3.5
	2.0	1.7	8.5	1.1	12	5.3	5.3	2.8	18	4.4	8.5
Settleable Solids(3)(5)	0.1 ml/l	-1	0	0	0	0	0	0	0	0	0
(3)	0.2	-0.8	–	–	–	–	–	–	–	–	–
Suspended Solids (3)	50	-0.2	20	0.5	14	0.6	2.2	2.8	7.8	0.1	7.7
(3)	75	0.2	30	1.5	21	1.7	3.9	4.9	12	1.1	12
(4)	45	-0.3	18	0.3	12	0.4	1.9	2.4	6.9	-0.1	6.8
(4)	30	-0.6	11	-0.3	7.7	-0.2	0.9	1.2	4.2	-0.8	4.0
(5)	15	-0.9	5.1	-0.9	3.2	-0.9	-0.1	0.0	1.5	-1.4	1.2
Turbidity (3)	50	2.5	66	8.2	33	9.5	3.7	6.5	35	3.0	12
(FTU) (3)	75	4.3	100	13.6	49	15	6.1	11	53	5.3	20
(5)	10	-0.6	12	-0.6	5.5	0.4	-0.1	0.1	5.6	-0.7	1.4
BIOASSAYS											
Toxicity (3)	2.0	–	1.1	–	–	3.2	1.9	–	–	1.4	-0.2
(tu) (3)	1.5	–	0.6	–	–	2.2	1.2	–	–	0.8	-0.4
TICH (3)(5)	0.002	11	17	13	20	32	24	3.8	22	26	31
	0.004	24	34	27	41	66	48	8.6	46	54	64

constituent of concern in one or more of the SWRCB, the RWQEB, or the EPA requirements. The values are entirely relative and serve only to evaluate the relative reliability of the processes in relation to the concentration level of a particular constituent requirement. A negative value indicates a lower degree of reliability, but does not necessarily mean that the process does not meet the requirement. This coefficient of reliability factor was developed by the San Francisco Department of Public Works as a tool for process evaluation. The procedure for calculating the Coefficient of Reliability is shown in Appendix C.

SECTION X

SECTION X
ECONOMIC EVALUATION OF THE PROCESS TRAINS

INTRODUCTION

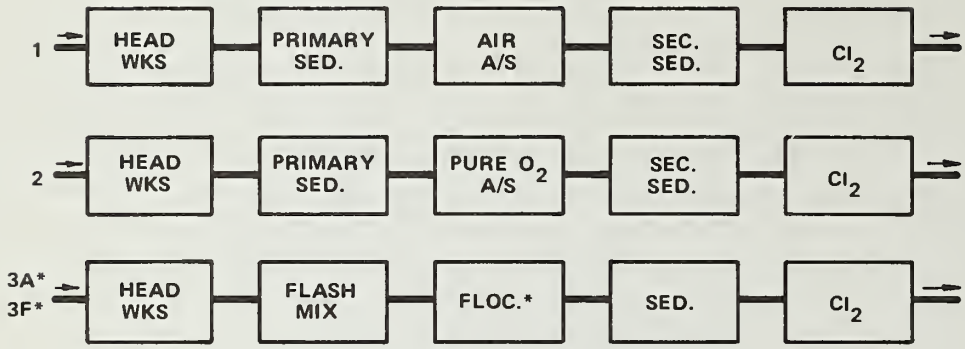
General

As a result of the San Francisco pilot plant studies, several treatment process trains were selected for an "order of magnitude" economic evaluation. Figures 10-1 and 10-2 illustrate these trains as categorized to meet EPA standards, SWRCB ocean, and RWQCB tentative Bay Discharge Standards for the North Point-Southeast and the Richmond-Sunset plants.

Purpose

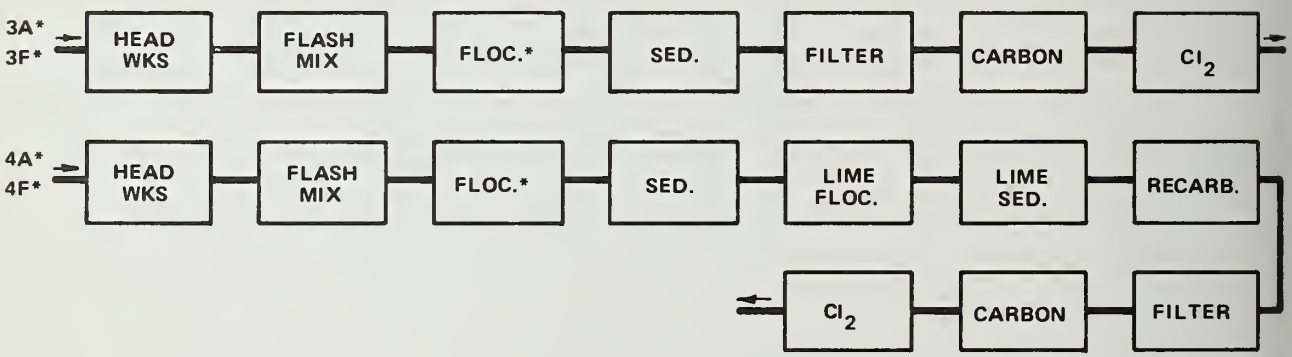
The purpose of the economic evaluation was to develop a basis for economic comparison among the process trains. The comparison includes capital and operating costs for the liquid and solids handling unit processes shown in Figures 10-1 and 10-2. Solids handling unit processes were defined as gravity thickening of raw and ferric chloride sludges, air flotation of activated alum and cationic sludges, anaerobic digestion of the combined sludges, vacuum filtration of the digested sludges and landfill disposal of the filter cake. The methodology for cost comparisons was based on the Federal Environmental Protection Agency's "Cost Effectiveness Analysis Guidelines," as published in the Federal Register, Vol. 38, No. 174 - September 10, 1973.

A. TRAINS TO MEET STATE OCEAN DISCHARGE STANDARDS



B. TRAINS TO MEET EPA STANDARDS

1. SAME AS A-1 ABOVE
2. SAME AS A-2 ABOVE



C. TRAINS TO MEET RWQCB TENTATIVE BAY DISCHARGE STANDARDS

1. SAME AS A-1 PLUS FILTER
2. SAME AS A-2 PLUS FILTER

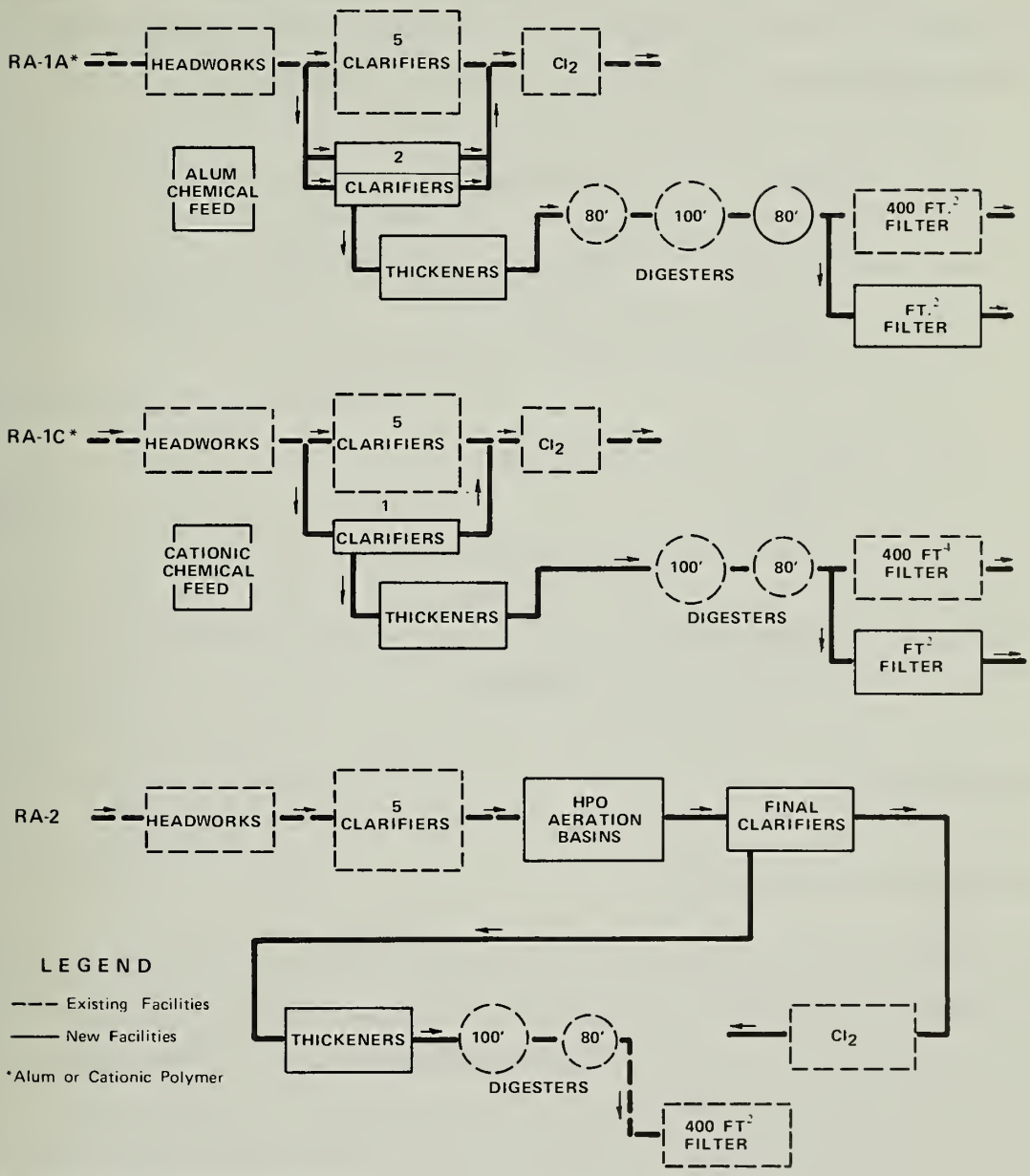
3A AND F SAME AS B-3A AND F

4A AND F SAME AS B-4A AND F

*ALUM OR FERRIC CHLORIDE

FIGURE 10-1
NORTH POINT – SOUTHEAST
PROCESS TRAINS SELECTED FOR
AN ECONOMIC EVALUATION

A. TRAINS TO MEET STATE OCEAN DISCHARGE STANDARDS



B. TRAINS TO MEET EPA STANDARDS

RB-1 SAME AS RA-2

FIGURE 10-2

RICHMOND–SUNSET
PROCESS TRAINS SELECTED FOR
ECONOMIC EVALUATION

ECONOMIC EVALUATION OF THE PROCESS TRAINS

The remaining text is organized as shown below. The specific data used to size each unit process are illustrated in the Appendix F under each process train.

- Summary and Conclusions
- Evaluation Technique and Accuracy
  - Present Value Technique
  - Expected Accuracy of Estimate
- Methods and Criteria
  - Capital
  - Operating and Maintenance
- Comparison of Physical/Chemical Treatment and Activated Sludge

Assumptions

North Point-Southeast-

Since the purpose of the reported estimates of cost is only to provide a basis for economic comparison of the candidate processes, it has been assumed that all North Point-Southeast facilities will be constructed on flat level cleared ground providing good foundation conditions. The estimates do not include any allowance for land cost. In addition, no recognition has been given to the value of existing facilities. For this report it has been assumed that these facilities will be equally valuable to all process trains.

Richmond-Sunset

The Richmond-Sunset estimates are based on the assumption that the existing units will be continued in use and only those units necessary to upgrade the plant to the indicated process train are included in the estimates. The operation, maintenance, and repair costs include the cost of operating the entire process train including the existing facilities.

SUMMARY AND CONCLUSIONS

Summary

The present value of total capital, operating, and maintenance costs for each process train and discharge requirement, as well as area requirements, are summarized for the North Point-Southeast Plant in Table 10-1. The present value costs are shown in Table 10-2. Table 10-3 and 10-4 provide similar cost summaries for the Richmond-Sunset Plant.

All present value costs represent an "Order of Magnitude" estimate which is defined to be accurate within +50 percent or -30 percent. The expected accuracy of these present value estimates is discussed further in this section under the heading "Evaluation Technique and Accuracy."

North Point-Southeast Conclusions

1. Within the expected accuracy of the analysis, the present value of costs for air activated sludge and high purity oxygen activated sludge can be considered

TABLE 10-1

NORTH POINT – SOUTHEAST
CAPITAL AND OM&R COSTS AND AREA REQUIREMENTS
FOR SELECTED PROCESS TRAINS

PROCESS TRAINS	REQUIRED AREA IN ACRES	ESTIMATED[1] COST[2] CAPITAL IN $1,000	OM&R IN $1,000
STATE OCEAN DISCHARGE STANDARDS			
Train A-1 (Air Activated Sludge)	70	$ 63,590	$ 4,270
Train A-2 (HPO Activated Sludge)	60	58,280	3,910
Train A-3-A (Alum PP/C)	55	42,760	6,410
Train A-3-F (Ferric PP/C)	55	40,850	6,650
EPA DISCHARGE STANDARDS			
Train B-1 (Air Activated Sludge)	70	63,590	4,270
Train B-2 (HPO Activated Sludge)	60	58,280	3,910
Train B-3-A (ALUM TP/C)	70	94,120	9,890
Train B-3-F (FERRIC TP/C)	70	92,050	10,140
Train B-4-A (Alum TP/C with Lime Treatment)	100	140,360	12,730
Train B-4-F (Ferric TP/C with Lime Treatment)	100	138,450	12,970
RWQCB TENTATIVE BAY DISCHARGE STANDARDS			
Train C-1 (Air Activated Sludge with Filtration)	80	82,100	4,920
Train C-2 (HPO Activated Sludge with Filtration)	70	76,330	4,560
Train C-3-A (Alum TP/C)	70	94,120	9,890
Train C-3-F (Ferric TP/C)	70	92,050	10,140
Train C-4-A (Alum TP/C with Lime Treatment)	100	140,360	12,730
Train C-4-F (Ferric TP/C with Lime Treatment)	100	138,450	12,970

(1) Order of magnitude level cost estimate.

(2) Systems and facilities to result in complete operating treatment plant, including but not limited to administration building, maintenance building, laboratories, piping, plumbing, electrical, instrumentation and control, site work and landscaping.

TABLE 10-2

NORTH POINT-SOUTHEAST
PRESENT VALUE OF CAPITAL AND OM&R COSTS[1],[2]
FOR SELECTED PROCESS TRAINS

PROCESS TRAINS	CAPITAL[3],[4] PRESENT VALUE IN $1,000	OM&R[5] PRESENT VALUE IN $1,000	TOTAL PRESENT VALUE IN $1,000
STATE OCEAN DISCHARGE STANDARDS			
Train A-1 (Air Activated Sludge)	$ 53,870	$ 40,530	$ 94,400
Train A-2 (HPO Activated Sludge)	49,370	37,160	86,530
Train A-3-A (Alum PP/C)	36,230	60,910	97,140
Train A-3-F (Ferric PP/C)	34,610	63,190	97,800
EPA DISCHARGE STANDARDS			
Train B-1 (Air Activated Sludge)	53,870	40,530	94,400
Train B-2 (HPO Activated Sludge)	49,370	37,160	86,530
Train B-3-A (Alum TP/C)	79,740	93,890	173,630
Train B-3-F (Ferric TP/C)	77,990	$ 96,240	174,230
Train B-4-A (Alum TP/C with Lime Treatment)	118,920	120,900	239,820
Train B-4-F (Ferric TP/C with Lime Treatment)	117,300	123,180	240,480
RWQCB TENTATIVE BAY DISCHARGE STANDARDS			
Train C-1 (Air Activated Sludge with Filtration)	69,200	46,640	115,840
Train C-2 (HPO) Activated Sludge with Filtration)	67,630	43,300	110,930
Train C-3-A (Alum TP/C)	79,740	93,890	173,630
Train C-3-F (Ferric TP/C)	77,990	96,240	174,230
Train C-4-A (Alum TP/C with Lime Treatment)	118,920	120,900	239,820
Train C-4-F (Ferric TP/C with Lime Treatment)	117,300	123,180	240,480

(1) Order of magnitude level cost estimate.

(2) Systems and facilities to result in complete operating treatment plant, including but not limited to administration building, maintenance building, laboratories, piping, plumbing, electrical; instrumentation and control, site work and landscaping.

(3) Present (January 1974) value of all costs through December 1997 at 5.625% annual discount rate.

(4) Expenditure schedule for capital costs assumed at 5% in 1974, 20% in 1975, 40% in 1976 and 35% in 1977.

(5) At indicated constant annual rate of expenditure for 20 years (1978 through 1997).

TABLE 10-3

RICHMOND-SUNSET
CAPITAL AND OM&R COSTS AND AREA REQUIREMENTS
FOR SELECTED PROCESS TRAINS

PROCESS TRAINS	ADDITIONAL REQUIRED AREA IN ACRES	ESTIMATED[1] COST[2] CAPITAL IN $1,000	OM&R IN $1,000
STATE OCEAN DISCHARGE STANDARDS			
Train RA-2 (HPO Activated Sludge)	10	$14,590	$1,040
Train RA-3A (Alum PP/C)	None	6,690	1,670
Train RA-3C (Cationic PP/C)	None	4,830	2,760
EPA DISCHARGE STANDARDS			
Train RB-2 (HPO Activated Sludge)	10	14,590	1,040

(1) Order of magnitude level cost estimate.

(2) Systems and facilities to result in complete operating treatment plant, including but not limited to administration building, maintenance building, laboratories, piping, plumbing, electrical, instrumentation and control, site work and landscaping.

TABLE 10-4

RICHMOND–SUNSET
PRESENT VALUE OF CAPITAL AND OM&R COSTS[1],[2]
FOR SELECTED PROCESS TRAINS

PROCESS TRAINS	CAPITAL[3],[4] PRESENT VALUE IN $1,000	OM&R[5] PRESENT VALUE IN $1,000	TOTAL PRESENT VALUE IN $1,000
STATE OCEAN DISCHARGE STANDARDS			
Train RA-2 (HPO Activated Sludge)	$12,360	$ 9,910	$22,270
Train RA-3A (Alum PP/C)	5,670	15,880	21,550
Train RA-3C (Cationic PP/C)	4,090	26,240	30,330
EPA DISCHARGE STANDARDS			
Train RA-2 (HPO Activated Sludge)	12,360	9,910	22,270

(1) Order of magnitude level cost estimate.

(2) Systems and facilities to result in complete operating treatment plant, including but not limited to administration building, maintenance building, laboratories, piping, plumbing, electrical; instrumentation and control, site work and landscaping.

(3) Present (January 1974) value of all costs through December 1997 at 5.625% annual discount rate.

(4) Expenditure schedule for capital costs assumed at 5% in 1974, 20% in 1975, 40% in 1976 and 35% in 1977.

(5) At indicated constant annual rate of expenditure for 20 years (1978 through 1997).

equal for all discharge standards. The choice between air and oxygen should be based on the amount of land required for the treatment facility, the anticipated process efficiencies, and the degree of process reliability.

2. For the SWRCB Ocean Discharge Requirements, the present value costs for primary physical/chemical treatment and activated sludge treatment can be considered equal. As with conclusion number one, the choice between the two types of treatment trains should be based on land requirements, process efficiencies, and process reliability.

3. For the EPA Discharge Requirements, the present value cost of tertiary physical/chemical treatment is significantly higher than activated sludge.

4. For the RWQCB Tentative Bay Discharge Requirement, the present value cost of activated sludge with filtration is much lower than tertiary physical/chemical treatment.

5. The present value cost of two stage chemical treatment (trains B-4 and C-4) is significantly more expensive than any of the other process trains.

6. The difference in present value cost between the use of alum and ferric chloride coagulants is insignificant. Process considerations such as coagulation effectiveness and sludge handling should be the basis for selection between alum and ferric chloride.

Richmond-Sunset Conclusions

1. Excluding the cost of additional land, the present value of the cost of providing high purity oxygen activated sludge treatment and that of primary physical/chemical treatment with alum coagulation are equal.

2. The present value of the cost of providing primary physical/chemical treatment with cationic polymer coagulation is considerably more than either HPO A/S or alum PP/C treatment.

EVALUATION TECHNIQUE AND ACCURACY

Present Value Technique

Present value is an economic method of evaluation which considers the time value of money to be spent in the future. At a specified interest rate and with given payments made at future time intervals, present worth analysis will yield the "present value" of future monies spent.

Present value techniques allow direct comparison of alternative future payment sequences varying in amounts and times.

Expected Accuracy of Estimates

Words such as "order of magnitude," budget estimate," "preliminary cost estimates," and "engineer's estimate" mean

many things to many people. Further, the range of accuracy is poorly defined.

In order to help solve these problems, the terms and accuracy ranges selected by the American Association of Cost Engineers were used. Table 10-5 describes the terms.

The "order of magnitude estimate" with an expected accuracy of +50 percent or -30 percent was used for the economic comparisons of the different process trains.

METHODS AND ASSUMPTIONS

Capital Costs

Source Material-

Four principal sources of information were used to develop the capital costs for each of the unit processes. The sources were:

- "Montgomery County Regional AWT Plant," a predesign study by CH2M HILL, Consulting Engineers.
- "Estimating Costs and Manpower Requirements for Conventional Wastewater Treatment Facilities," EPA Publication 17090 DAN 10/71, by Black and Veatch, Consulting Engineers.

TABLE 10-5

EXPECTED ACCURACY OF COST ESTIMATES

TYPE OF ESTIMATE	TYPE OF ENGINEERING STUDY
Order of Magnitude Estimate — This is an approximate estimate made without detailed engineering data. Some examples would be: an estimate from cost-capacity curves, an estimate using scaleup or scaledown factors, and an approximate ratio estimate. It is normally expected that an estimate of this type would be accurate within +50% or -30%.*	COMPREHENSIVE STUDY
Budget Estimate — Budget in this case applies to the owner's budget, and not to the budget as a project-control document. A budget estimate is prepared with the use of flowsheets, layouts and equipment details. It is normally expected that an estimate of this type would be accurate within +30% or -15%*	PREDESIGN STUDY
Definitive Estimate — As the name implies this is an estimate prepared from very defined engineering data. As a minimum, the data must include: fairly complete plot plans and elevations, piping and instrument diagrams, one-line electrical diagrams, equipment data sheets and quotations, structural sketches, soil data and sketches of major foundations, building sketches and a complete set of specifications. The "maximum" definitive estimate would be made from "Approved for Construction" drawings and specifications. It is expected that a definitive estimate would be accurate within +15% and -5%.*	ENGINEERS ESTIMATE AT TIME OF CONTRACT BIDDING

*Prepared by the American Assn. of Cost Engineers.

ECONOMIC EVALUATION OF THE PROCESS TRAINS

- "Process Design Manual for Carbon Adsorption," Environmental Protection Agency, October 1973.

- "Technical and Economic Review of Advanced Waste Treatment Processes," Prepared for U.S. Corps of Engineers by Environmental Quality Systems Inc., March 1973.

- "Sewage Treatment Plant Expansion," Metropolitan Denver Sewage Disposal District No. 1.

The Montgomery County Advanced Wastewater Treatment Facility incorporates both air activated sludge and tertiary treatment. The liquid handling unit processes included in the project are screening, grinding, grit removal, primary clarification, complete mix air activated sludge and secondary clarification, lime coagulation and clarification, two stage recarbonation, filtration, and carbon regeneration.

Solids handling processes included in the Montgomery County facility are gravity thickening, air flotation, anaerobic digestion, lime recovery, and carbon regeneration. The plant flow is 60 mgd average day, and 90 mgd maximum day. Cost estimates were based on a very detailed predesign study.

January 1974 bid prices from the Denver project were used to adjust the Montgomery County estimates.

ECONOMIC EVALUATION OF THE PROCESS TRAINS

Methodology-

Step 1: The process conclusions concerning the pilot plant performance on the combined North Point-Southeast waste flow and the Richmond-Sunset waste flow were developed. Table 10-6 illustrates the major criteria. Detailed criteria for each unit process are described in Appendix F. Where information was not yet available, values reported in the literature were used.

Step 2: The criteria developed in Step 1 were used to estimate recycle flows, solids production, and finally to size treatment units. The number of units and their sizes are reported in Appendix F for each unit process.

Step 3: The unit process numbers and sizes were then used to scale up estimates for Montgomery County and to modify cost curves found in the latter four cost sources presented earlier.

Step 4: The unit process capital costs were adjusted to the City of San Francisco as of January 1974. An EPA Index of 208 was assumed for San Francisco. A 4.6 percent adjustment for engineering services and a 0.4 percent adjustment for legal, fiscal, and administrative costs were applied to each unit process capital cost. In addition a contingency of 15 percent was applied for data taken from Montgomery County and 25 percent was applied to data taken from cost curves. The capital costs listed for each unit process in the

TABLE 10-6

MAJOR DESIGN CRITERIA

ITEM	VALUE	
Average Hydraulic Capacity	100	mg
Peak Hydraulic Capacity, 24-72 hours	180	mg
Primary Effluent BOD		
Average Concentration at 100 mgd	155	mg/l
Peak Concentration at 100 mgd	270	mg/l
Flash Mixing at Average Flow	1	min.
Flocculation at Average Flow	14	min.
Clarification		
Primary at Peak Flow	1,000	gpd/ft^2
Physical – Chemical Primary at Peak Flow*	1,000	gpd/ft^2
Activated Sludge – Secondary		
Air at Average Conditions	430	gpd/ft^2
	16	$lbs/day/ft^2$
High Purity Oxygen at Average Conditions	550	gpd/ft^2
	33	$lbs/day/ft^2$
Lime at Average/Peak Flows	1,100/2,000	gpd/ft^2
Recarbonation at Average/Peak Flows	1,100/2,000	gpd/ft^2
Activated Sludge		
Air at Average Conditions	0.17	lbs BOD/MLVSS/day
at Average Conditions	1.2	lbs O_2/lb BOD Rem.
High Purity Oxygen at Average Conditions	0.35	lbs BOD/MLVSS/day
at Average Conditions	1.5	lbs O_2/lb BOD Rem.
Filtration Net Output at Peak Flow	4	gpm/ft^2
Carbon Adsorption – at Average Flow	4	gpm/ft^2
at Average Flow	36	min.
Carbon Regeneration–at Average Flow	1,300	lbs/mg
Solids Processing		
Gravity Thickening Primary Sludge	20	$lbs/ft^2/day$
Flotation Thickening of Waste A/S (Air)	2.0	$lbs/ft^2/hr$
(Oxygen)	3.0	$lbs/ft^2/hr$
Anaerobic Digestion of all Sludges	0.10	lbs $VSS/ft^3/day$
	20	days
Vacuum Filtration of Digested Primary and Waste A/S	4	$lbs/ft^2/hr$
Thickening of Chemical/Primary Sludges		
Alum – Flotation	2	$lbs/ft^2/hr$
Ferric Chloride – Gravity	15	$lbs/ft^2/day$
Vacuum Filter of Digested		
Chemical/Primary Sludge	1	$lbs/ft^2/hr$

*Physical/Chemical Primary Peak Flow at R-S

Alum	1,600	gpd/ft^2
Cationic Polymer	2,000	gpd/ft^2

appendix include January 1974 costs with engineering, legal, administrative, and contingency adjustments.

Step 5: To determine the present value cost of each unit process, the following assumptions were made. All costs were discounted at an annual rate of 5.625 percent as directed by the City of San Francisco. Further, the expenditure schedule for capital costs was assumed to be 5 percent in 1974, 20 percent in 1975, 40 percent in 1976, and 35 percent in 1977. The combined adjustment factor was 0.8472.

Step 6: For the North Point-Southeast estimates the individual unit processes were combined to form the originally defined process trains. A factor of 16 percent was then applied to account for administrative and maintenance buildings, laboratories, yard piping, plumbing, electrical, special instrumentation and controls, site work, and landscaping. A table at the beginning of each process train in the appendix summarizes the capital costs for that train.

Step 7: Each process train was then laid out to determine approximate area requirements. No specific efforts were made to develop a compact site. However, rectangular tankage was selected in recognition of the probable area problems facing the City of San Francisco.

Step 8: For the Richmond-Sunset estimates it was assumed that the existing administration and laboratory facilities would be adequate for the expanded plant. A factor of 15 percent was added to the project cost

in recognition of the difficulties involved in remodeling this plant because of the confined area and the need to continue the plant in operation during construction.

Operating and Maintenance Costs

Source Material-

Unit costs for operations and maintenance were developed from information supplied by the City of San Francisco, chemical suppliers, and utility companies.

Table 10-7 illustrates the unit costs used for this study. The number of man-hours needed for each unit process was estimated by using the EPA Publication "Estimating Staffing for Municipal Wastewater Treatment Facilities" and adjusting for plant size.

Methodology-

Step 1: The unit costs illustrated in Table 10-7 were applied to each of the operating and maintenance categories. Power and fuel requirements were scaled up from equipment requirements of Montgomery County. Chemical costs were based both on sludge production estimates and upon chemical dosages developed from the pilot plant study. Table 10-8 illustrates the chemical doses. The operating costs for each unit process are listed in Appendix F.

Step 2: The present value of the operating costs was then computed. All operating costs were discounted at an annual rate of 5.625 percent. Further, it

TABLE 10-7

OPERATIONS, MAINTENANCE AND REPAIR UNIT PRICES

ITEM	VALUE
LABOR (Includes fringe benefits)	
Supervisory	16.00 $/hr
Operation	9.50 $/hr
Maintenance	9.50 $/hr
Laboratory	10.50 $/hr
Clerical	4.50 $/hr
Yard Work	4.85 $/hr
POWER	1.345¢/kW hr
FUEL	10.8 ¢/Therm
CHEMICALS	
Chlorine	59.00 $/ton Cl_2
Sulfur Dioxide	95.00 $/ton SO_2
Polymers	
Flotation (Trains A-1,B-1,A-3,B-3,C-3,E-1,B-4, C-4)	7.00 $/ton solids
(Trains A-2,B-2,C-2)	4.00 $/ton solids
Vacuum Filtration	
(Trains A-1,B-1,A-2,B-2,C-1,C-2)	6.00 $/ton solids
(Trains A-3,B-3,C-3,B-4,C-4)	14.00 $/ton solids
Coagulation Aid (Anionic)	1.20 $/lb polymer
Filtration Aid	1.20 $/lb polymer
Lime Dewatering	1.20 $/lb polymer
Cationic	102.00 $/ton Cationic
Alum	38.00 $/ton Alum
Lime	26.00 $/ton Lime
Sodium Nitrate	100.00 $/ton $NaNO_3$
Make-Up Carbon	0.32 $/lb carbon
Ferric Choride	76.85$/ton $FeCl_3$
REPLACEMENT PARTS (Maintenance)*	
Headworks	0.56%
Primary Treatment	0.40%
Air Activated Sludge	0.56%
High Purity O_2 Activated Sludge	0.56%
Flash Mix, Flocculation, and Chemical Clar.	0.40%
Filtration	0.80%
Carbon Adsorption and Regeneration	0.50%
Post Chlorination and Dechlorination	0.40%
Organic Solids Thickening, Digestion and Dewatering	1.36%
Lime Treatment	0.50%
Lime Solids Processing	1.36%
Ancillary Systems and Facilities	0.40%
Sludge Haul	5.50 $/wet ton

*Percent of Capital after Engineering, Legal, Admin. and Contingencies.

TABLE 10-8

CHEMICAL DOSAGES BASED ON PILOT PLANT EVALUATIONS

NORTHPOINT–SOUTHEAST

ITEM	VALUE
PHYSICAL/CHEMICAL COAGULATION	
WITH ALUM	
Alum	275 mg/l
Lime	80 mg/l
Polymer (Anionic)	0.5 mg/l
WITH FERRIC CHLORIDE	
Ferric Chloride	175 mg/l
Lime	100 mg/l
Polymer	0.5 mg/l
LIME COAGULATION	
Lime	470 mg/l
Polymer	0.5 mg/l
CARBON DOSE	1,300 lbs/mg
SODIUM NITRATE	5.0 mg/l

RICHMOND–SUNSET

ITEM	VALUE
PHYSICAL/CHEMICAL COAGULATION	
WITH ALUM	
Alum	350 mg/l
Lime	20 mg/l
Anionic Polymer	1 mg/l
WITH CATIONIC POLYMER	
Cationic Polymer	450 mg/l
Anionic Polymer	1 mg/l

was assumed that there would be a constant annual rate of operating cost expenditures for 20 years, beginning with 1978. The overall present value factor for operating and maintenance cost was 9.502.

SECTION XI

SECTION XI

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SECTION XII

SECTION XII

GLOSSARY AND ABBREVIATIONS

GLOSSARY

ACTIVATED CARBON. Carbon particles usually obtained by carbonization of cellulosic material in the absence of air and possessing a high adsorptive capacity.

ACTIVATED SLUDGE PROCESS. A biological wastewater treatment process in which a mixture of wastewater and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater (mixed liquor) by sedimentation and wasted or returned to the process as needed.

ALKALINITY. The capacity of water to neutralize acids, a property imparted by the water's content of carbonates, bicarbonates, hydroxides, and occasionally borates, silicates, and phosphates. It is expressed in milligrams per liter of equivalent calcium carbonate.

ALUM. A common name, in the water and wastewater treatment field, for commercial-grade aluminum sulfate. Dosage of alum as $Al_2(SO_4)_3 \cdot 14(H_2O)$.

ALUMINUM SULFATE. A chemical, formerly sometimes called "waterworks alum" in water or wastewater treatment, prepared by combining a mineral known as bauxite with sulfuric acid.

ANAEROBIC DIGESTION. The degradation of organic matter brought about through the action of microorganisms in the absence of elemental oxygen.

ANAEROBIC WASTE TREATMENT. Waste stabilization brought about through the action of microorganisms in the absence of air or elemental oxygen. Usually refers to waste treatment by methane fermentation.

ANIONIC POLYMER. A polymeric compound with net negative charge. Used primarily as a coagulant aid.

BIOCHEMICAL OXYGEN DEMAND (BOD). A standard test used in assessing wastewater strength. The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions.

BIOLOGICAL WASTEWATER TREATMENT. Forms of wastewater treatment in which bacterial or biochemical action is intensified to stabilize, oxidize, and nitrify the unstable organic matter present. Intermittent sand filters, contact beds, trickling filters, and activated sludge processes are examples.

GLOSSARY AND ABBREVIATIONS

BOD LOAD. The BOD content, usually expressed in pounds per unit of time, of wastewater passing into a waste treatment system or to a body of water.

CATIONIC POLYMER. A polymeric compound with a net positive charge. Used as a primary coagulant.

CHEMICAL OXYGEN DEMAND (COD). A measure of the oxygen-consuming capacity of inorganic and organic matter present in water or wastewater. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specific test. It does not differentiate between stable and unstable organic matter and thus does not necessarily correlate with biochemical oxygen demand. Also known as OC and DOC, oxygen consumed and dichromate oxygen consumed, respectively.

CLARIFICATION. Any process or combination of processes the primary purpose of which is to reduce the concentration of suspended matter in a liquid.

CLARIFIED WASTEWATER. Wastewater from which most of the settleable solids have been removed by sedimentation. Also called settled wastewater.

CLARIFIER. A unit of which the primary purpose is to secure clarification. Usually applied to sedimentation tanks or basins. See sedimentation tank.

COMBINED SEWER. A sewer intended to receive both wastewater and storm or surface water.

COMBINED WASTEWATER. A mixture of surface runoff and other wastewater such as domestic or industrial wastewater.

COMMINUTION. The process of cutting and screening solids contained in wastewater flow before it enters the flow pumps or other units in the treatment plant.

COAGULANT AID. Any chemical or substance used to assist or modify coagulation.

COAGULATION. In water and wastewater treatment, the destabilization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical or by biological processes.

FERRIC. Commercial-grade ferric chloride. Dosage of ferric given as $FeCl_3$.

FERRIC CHLORIDE. A soluble iron salt, $FeCl_3$, formed by the superchlorination of waste pickle liquor, $FeCl_2$.

FILTERED WASTEWATER. Wastewater that has passed through a mechanical filtering process but not through a trickling filter bed.

FILTER LOADING. Hydraulically, the quantity of liquid applied per unit of filter bed area or volume per day.

FILTERABLE EFFLUENT. A sedimentation basin effluent that will be able to produce filter runs of 8-hour duration before the headloss across the filter exceeds 14 inches of mercury at a hydraulic filter loading of 4 gpm/sq ft. The filtrate must also have an effluent turbidity less than 5 FTU.

FILTER RUN. (1) The interval between the cleaning and washing operations of a rapid sand filter. (2) The interval between the changes of the filter medium on a sludge dewatering filter.

FILTRATE. The liquid which has passed through a filter.

FILTRATION. The process of passing a liquid through a filtering medium (which may consist of granular material, such as sand, magnetite, or diatomaceous earth, finely woven cloth, unglazed porcelain, or specially prepared paper) for the removal of suspended or collodial matter.

FLOC. Small gelatinous masses formed in a liquid by the reaction of a coagulant added thereto, through biochemical processes, or by agglomeration.

FLOCCULATING TANK. A tank used for the formation of floc by the gentle agitation of liquid suspensions, with or without the aid of chemicals.

FLOCCULATION. The agglomeration of colloidal and finely divided suspended matter after coagulation by gentle stirring by either mechanical or hydraulic means. In biological wastewater treatment where coagulation is not used, agglomeration may be accomplished biologically.

FLOCCULATOR. (1) A mechanical device to enhance the formation of floc in a liquid. (2) An apparatus for the formation of floc in water and wastewater.

FOAM. A collection of minute bubbles formed on the surface of a liquid by agitation, fermentation, etc.

FOOD TO MICROORGANISM RATIO (FM). The ratio of the pounds of biochemical oxygen demand removed to the pounds of activated solids biomass.

HIGH PURITY OXYGEN ACTIVATED SLUDGE. Activated sludge process utilizing pure oxygen for aeration.

HYDROGEN-ION CONCENTRATION. The weight of hydrogen ion in moles per liter of solution. Commonly expressed as the pH value, which is the logarithm of the reciprocal of the hydrogen-ion concentration.

LIME. Any of a family of chemicals consisting essentially of calcium hydroxide made from limestone (calcite) which is composed almost wholly of calcium carbonate or a mixture of calcium and magnesium carbonate. Lime dosage given as dosage of $Ca(OH)_2$.

MEAN CELL RESIDENCE TIME. The total active microbial mass in the activated sludge treatment system divided by the total quantity of microbial mass withdrawn daily from the system.

MIXED LIQUOR. A mixture of activated sludge and organic matter undergoing activated sludge treatment in the aeration tank.

MIXING BASIN. A basin or tank wherein agitation is applied to water, wastewater, or sludge to increase the dispersion rate of applied chemicals; also, a tank used for general mixing purposes.

OVERFLOW RATE. One of the criteria for the design of settling tanks in treatment plants; expressed in gallons per day per square foot of surface area in the settling tank.

PRIMARY COAGULANT. A compound responsible for coagulation; a floc-forming agent.

PRIMARY PHYSICAL/CHEMICAL TREATMENT. Treatment consisting of the addition of coagulant chemicals to the wastewater followed by sedimentation basins. The sedimentation basin effluent is the final effluent.

RETURNED ACTIVATED SLUDGE. Settled activated sludge returned to mix with incoming raw or primary settled wastewater.

SEDIMENTATION BASIN. A basin or tank in which water or wastewater containing settleable solids is retained to remove by gravity a part of the suspended matter. Also called sedimentation tank, settling basin, settling tank.

SLUDGE. (1) The accumulated solids separated from liquids, such as water or wastewater, during processing, or deposits on bottoms of streams or other bodies of water. (2) The precipitate resulting from chemical treatment, coagulation, or sedimentation of water or wastewater.

SLUDGE TREATMENT. The processing of wastewater sludges to render them innocuous. This may be done by aerobic or anaerobic digestion followed by drying on sand beds, filtering, and incineration, filtering and drying, or wet air oxidation.

SLUDGE VOLUME INDEX (SVI). The ratio of the volume in milliliters of sludge settled from a 1,000-ml sample in 30 minutes to the concentration of mixed liquor in milligrams per liter multiplied by 1,000.

SODIUM HYDROXIDE. A strong caustic chemical used in treatment processes to neutralize acidity, increase alkalinity, or to raise the pH value. Also known as caustic soda, sodium hydrate, lye, and white caustic. Chemical symbol is NaOH.

SUSPENDED SOLIDS. (1) Solids that either float on the surface of, or are in suspension in, water, wastewater, or other liquids, and which are largely removable by laboratory filtering. (2) The quantity of material removed from wastewater in a laboratory test, as prescribed in "Standard Methods for the Examination of Water and Wastewater" and referred to as nonfilterable residue.

TERTIARY PHYSICAL/CHEMICAL TREATMENT. Treatment consisting of the addition of coagulant chemicals to the wastewater followed by sedimentation, filtration, and activated carbon. The activated carbon effluent is the final effluent.

TURBIDITY. (1) A condition in water or wastewater caused by the presence of suspended matter, resulting in the scattering and adsorption of light rays. (2) A measure of fine suspended matter in liquids. (3) An analytical quantity usually reported in arbitrary turbidity units determined by measurements of light diffraction. Usually in Formazin Turbidity Units or Jackson Turbidity Units.

VOLATILE SOLIDS. The quantity of solids in water, wastewater, or other liquids, lost on ignition of the dry solids at 600° C.

ABBREVIATIONS

A/S - Activated sludge
BOD - Biochemical Oxygen Demand
COD - Chemical Oxygen Demand
cu m/day - cubic meters per day
cu m/day/sq m - cubic meters per day per square meter
EPA - Environmental Protection Agency
FTU - Formazin Turbidity Units
g/day/sq m - grams per day per square meter
gpd - gallons per day
gpd/sq ft - gallons per day per square foot
gpm - gallons per minute
gpm/sq ft - gallons per minute per square foot
HEM - Hexane extractibe material (oil and grease)
HPO - high purity oxygen
JTU - Jackson Turbidity Units
kg/sq cm - kilograms per square centimeter
l/min/sq m - liters per minute per square meter
lb/day/sq ft - pounds per day per square foot
MCRT - mean cell residence time
mgd - million gallons per day
mg/l - milligrams per liter
MLVSS - mixed liquor volatile suspended solids
pH - Hydrogen-ion concentration
ppb - parts per billion
PP/C - primary physical chemical
ppm - parts per million
psi - pounds per square inch
Q - flow rate
RASVSS - return activated sludge volatile suspended solids
RWQCB - Regional Water Quality Control Board
scfm - standard cubic foot per minute
SVI - sludge volume index
SWRCB - State Water Resources Control Board
TDS - Total Dissolved Solids
TP/C - tertiary physical/chemical
TS - Total Solids
TSS - total suspended solids
tu - toxicity units
VSS - volatile suspended solids

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